THE
LAW OF STORMS,
CONSIDERED PRACTICALLY.

W. H. ROSSER.

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LAW OF STORMS
CONSIDERED PRACTICALLY.

ILLUSTRATED WITH NUMEROUS WOODCUTS.

By W. H. ROSSER,

Author of the "Deviation of the Compass in Iron Ships Considered Practically," "How to Find the Stars," "The Seaman's Annual," &c., &c.

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PREFACE.

The progress of meteorology and a more systematized method of observation having developed new views in respect to the nature and origin of Storms, the subject has, during the last ten or dozen years, been one of continual discussion and much controversy. This work has been written to give, in brief, the history of the development of the Law of Storms,—to contrast the old "circular," with the later "spiral," theory,—and to show to what extent the old practical rules for storm-sailing require modification.

W. H. R.

157, Leadenhall Street,
London, *May*, 1876.

THE LAW OF STORMS

CONSIDERED PRACTICALLY.

Hurricane, Typhoon, and **Cyclone**[*] are but different names for the same natural phenomenon—a fierce tempest of wind and rain, with thunder and lightning, accompanied by a heavy cross sea, and marked by a very low barometer. The wind in such storms does not blow in straight lines, but, according to the popular idea, it has a horizontal rotation, as if on an axis; the centre of the storm is a calm, with the sea still rough, but the sun shining by day or the stars by night; immediately around this central calm area is the dark bank of cloud where the hurricane is blowing with its greatest strength; and a ship that has entered the calm with one wind leaves it with another blowing from an opposite, or nearly opposite, direction, indicating that while there is a movement of horizontal rotation, the storm-field is also subjected to a movement of translation.

Such tempests are especially characteristic of, though not confined to, the tropical regions; they very frequently invade extra-tropical regions, and even occasionally originate in the latter; they are subject to laws, as are all physical phenomena; and as it is of vital importance that a ship should not be navigated into or through the storm-field, which tradition and experience have alike pronounced to be disastrous, *practical rules* have been deduced from the *Law of Storms*, by the aid of which the seaman may avoid the danger, or escape from it when he happens to be caught there.

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[*] The term Hurricane comes through the Spanish *huracan*, which is said to be derived from a West Indian native word, imitative of *rushing wind*. Ty-foong is a Chinese word indicating a *great* or *mighty wind*. Cyclone, as applied to the revolving gales of Indian seas, is said to have first been used by Piddington in his *eighteenth* memoir on storms, which appeared in *Jour. Asiatic Soc. of Bengal*, vol. xviii.

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The literature relating to and bearing on storms and hurricanes is voluminous. In 1865, Mr. ANDRE POEY, of Havana, who has himself devoted much time and attention to meteorology, published a catalogue of 1,008 works, tracts, memoirs, reports, and papers—with a list of upwards of 500 authors and writers—all treating directly or indirectly on hurricanes and cyclonic storms, tropical and extra-tropical. Many of these productions date as far back as the 16th and 17th centuries; but, as a rule, the writers of that period, though familiar with the hurricanes of the West and East Indies, and the typhoons of the China Sea, were not adepts in even the crude meteorological science of the day: they conjectured much, while, on the other hand, they have given most graphic and accurate descriptions of the storms to the perils of which they were, as seamen, exposed, and to the destructive effects of which they were eye-witnesses: of the veering of the wind through several points of the compass, and of its mode of veering they say little or nothing, though they were not unacquainted with the fact that the wind changed from one quarter to its opposite, after an interval of calm. Later on there were more skilful observers, who made some shrewd guesses at truth while speculating on the phenomena that had fallen under their notice. But it is only since the commencement of the 19th century that anything *approximating* to correct ideas of the tremendous tropical hurricane has been worked out; the physical aspect, character and course of such storms attempted to be defined; and their seasons and range, within certain limits, ascertained.

It is probable that since 1865 until now, POEY'S catalogue has been augmented by not less than 300 additional works, memoirs, and papers, for meteorology has come to be a science of note, and the number of observers and enquirers in the field has largely increased. Surely, then, with such a mass of literature on a special department of the science of meteorology, the *Law of Storms* must now, for all essential purposes, be well understood, and the practical rules deduced from that law well collated and known, for on the accuracy of such knowledge and the readiness with which it can be applied depends the safety of life and property where ships are so constantly and in such numbers navigating the hurricane regions. It is proposed in these pages to show that the law of storms requires reconsideration, and a more thorough and critical examination of all the details on which it rests;—to show, in fact, that there are doubts as to its being as well known as it was thought to be, and this arising perhaps from an imperfect collating of facts,—perhaps from a too hasty generalization in respect to the facts,—or again from an erroneous conclusion that the physical characteristics of all hurricanes are identical. It may be as well, therefore, to commence by briefly tracing the history of the investigation of the law of storms; then, to note the progress of the development of that law in the past; at the same time bringing together the whole of the practical rules that have hitherto been laid down as applicable to navigation for the avoidance of the inner and most destructive part of the storm-field; and finally, to draw attention to the new views on hurricanes, as resulting from certain observations lately, but carefully, made in India, Mauritius, and Réunion, which have caused notable meteorologists to doubt the rotatory direction of these storm-winds, at least in the sense until now supposed,—and to dispute the strict accuracy of the so-called law of storms, together with *some* of the practical rules appertaining thereto, as propounded by many eminent men of science and writers during the last thirty or forty years, and whose opinions still carry great weight.

History.—COLUMBUS discovered America in 1492, and shortly afterwards Spanish writers describe the West Indian hurricane; amongst the earliest of these writers was FERNANDEZ DE OVIEDO, who, in his *Historia general y Natural de las Indias y Tierra Firme de la Mar Océano*, gives an account of the Santo Domingo hurricanes of 1508 (Aug. 3) and 1509. Taking the storm of 1508, which lasted 24 hours, he notes the destruction of houses, the loss of life, and also the immense havoc done in different parts of the island; he remarks that the wind commenced at North, driving ships from their moorings, and subsequently changed suddenly to an opposite quarter, blowing then from the South as violently and with as much fury as before from the North. The Indians distinguished these excessively tempestuous storms as *huracanes*.

WILLIAM DAMPIER, an English navigator and companion of some of the old buccaneers, was an intelligent observer and careful narrator of all he saw. He briefly describes the incidents and phenomena of the typhoon in the China Seas with an accuracy scarcely to be surpassed:—

"*Tuffoons* are a particular kind of violent Storms, blowing on the Coast of *Tonquin*, and the neighbouring Coasts in the Months of *July*, *August*, and *September*. They commonly happen near the full or change of the Moon, and are usually preceded by very fair weather, small Winds and a clear Sky. Those small Winds vere from the common Trade of that time of the year, which is here at S.W. and shuffles about to the N. and N.E. Before the Storm comes there appears a boding Cloud in the N.E. which is very black near the Horizon, but towards the upper edge it looks of a dark Copper colour, and higher still it is brighter, and afterwards it fades to a whitish glaring colour, at the very edge of the Cloud. This Cloud appears very amazing and ghastly, and is sometimes seen 12 Hours before the Storm comes. When that Cloud begins to move apace, you may expect the Wind presently. It comes on fierce, and blows very violent at N.E. 12 Hours more or less. It is also commonly accompanied with terrible claps of Thunder, large and frequent flashes of Lightning, and excessive hard Rain. When the Wind begins to abate it dies away suddenly, and falling flat calm, it continues so an hour, more or less: then the wind comes about to the S.W. and it blows and rains as fierce from thence, as it did before at N.E. and as long." (W. DAMPIER'S "*Voyages and Descriptions.*" Vol. II. p. 36.)

Dampier, being at St. John's Island* in July, 1687, encountered one of these tempests, and the following is his graphic account of what occurred:—

"It was now the time of the Year for the S.W. Monsoon, but the Wind had been whiffling about from one part of the Compass to another for two or three Days, and sometimes it would be quite calm. This caused us to put to Sea, that we might have Sea-room at least; for such flattering Weather is commonly the forerunner of a Tempest.

"Accordingly we weighed Anchor, and set out; yet we had very little Wind all the next Night. But the Day ensuing, which was the 4th Day of *July*, about Four a-Clock in the Afternoon, the Wind came to the N.E. and freshned upon us, and the Sky looked very black in that quarter, and the black Clouds began to rise apace and moved towards us; having hung all the Morning in the Horizon. This made us take in our Top-sails, and the Wind still increasing, about Nine a-Clock we rift our Main-sail and Fore-sail; at Ten we furl'd our Fore-sail, keeping under a Main-sail and Mizen. At Eleven a-Clock we furl'd our Main-sail, and ballasted our Mizen; at which time it began to rain, and by Twelve a-Clock at Night it blew exceeding hard, and the Rain poured down as through a Sieve. It thundered and lightned prodigiously, and the Sea seemed all of a Fire about us; for every Sea that broke sparkled like Lightning. The violent Wind raised the Sea presently to a great heighth, and it ran very short, and began to break in on our Deck. One Sea struck away the Rails of our Head, and our Sheet-Anchor, which was stowed with one Flook or bending of the Iron over the Ships Gunnal, and lasht very well down to the Side, was violently washt off, and had like to have struck a hole in our Bow, as it lay beating against it. Then we were forced to put right before the Wind to stow our Anchor again; which we did with much ado; but afterwards we durst not adventure to bring our Ship to the Wind again, for fear of foundring, for the turning the Ship either to or fro from the Wind is dangerous in such violent Storms. The Fierceness of the Weather continued till Four a-Clock that Morning; in which time we did cut away two Canoas that were towing astern.

"After Four a-Clock the Thunder and the Rain abated, and then we saw a *Corpus Sant* at our Maintop-mast Head, on the very Top of the Truck of the Spindle. This sight rejoiced our Men exceedingly; for the height of the Storm is commonly over when the *Corpus Sant* is seen aloft; but when they are seen lying on the Deck, it is generally accounted a bad Sign. * * * *

"We continued scudding right before Wind and Sea from Two till Seven a-Clock in the Morning, and then the Wind being much abated, we set our Mizen again, and brought our Ship to the Wind, and lay under a Mizen till Eleven. Then it fell flat calm, and it continued so for about two Hours: but the Sky looked very black and rueful, especially in the S.W. and the Sea tossed us about like an Egg-shell, for want of Wind. About One a-Clock in the Afternoon the Wind sprung up at S.W. out of the Quarter from whence we did expect it: therefore we presently brailed up our Mizen; and wore our Ship: But we had no sooner put our Ship before the Wind, but it blew a Storm again, and rain'd very hard, though not so violently as the Night before; but the Wind was altogether as boisterous, and so continued till Ten or Eleven a-Clock at Night. All which time we scuded and run before the Wind very swift, though only with our bare Poles, that is, without any Sail abroad. Afterwards the Wind died away by degrees, and before Day we had but little Wind, and fine clear Weather.

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* Changcum Island, S.W. of the entrance to Canton River.

"I was never in such a violent Storm in all my Life; so said all the Company."

It would seem probable that the old voyager was fated to experience another storm at the change of the next monsoon—which, if not altogether of full typhoon-force, was very cyclonic in its changes; he was then at an anchorage at one of the Bashees;—"We had yet the Winds at S.W. and S.S.W. mostly fair Weather. In *October* we did expect the Winds to shift to the N.E. and therefore we provided to sail (as soon as the eastern Monsoon was settled) to cruize off of *Manila*. Accordingly we provided a Stock of Provisions. * * * *

"About the 24th Day of *September* the Winds shifted about to the East, and from thence to the N.E. fine fair Weather. The 25th it came at N. and began to grow fresh, and the Sky began to be clouded, and the Wind freshned on us.

"At Twelve a-Clock at Night it blew a very fierce Storm. We were then riding with our best Bower a-Head; and though our Yards and Top-masts were down, yet we drove. This obliged us to let go our Sheet-anchor, veering out a good Scope of Cable, which stopt us till Ten or Eleven a-Clock the next Day. Then the Wind came on so fierce, that she drove again, with both Anchors a-head. The Wind was now at N. by W. and we kept driving till Three or Four a-Clock in the Afternoon: And it was well for us that there were no Islands, Rocks or Sands in our way, for if there had, we must have been driven upon them. We used our utmost Endeavours to stop here, being loth to go to Sea, because we had six of our Men ashore, who could not get off now. At last we were driven out into deep Water, and then it was in vain to wait any longer: Therefore we hove in our Sheet-Cable, and got up our Sheet-Anchor, and cut away our best Bower, (for to have heav'd her up then would have gone near to have foundred us) and so put to Sea. We had very violent Weather the Night ensuing, with very hard Rain, and we were forced to scud with our bare Poles till Three a-Clock in the Morning. Then the Wind slacken'd, and we brought our Ship to under a Mizen, and lay with our Head to the Westward. The 27th Day the Wind abated much, but it rained very hard all Day, and the Night ensuing. The 28th Day the Wind came about to the N.E. and it cleared up, and blew a hard Gale, but it stood not there, for it shifted about to the eastward, thence to the S.E. then to the South, and at last settled at S.W. and then we had a moderate Gale and fair Weather.

"It was the 29th Day when the Wind came to the S.W. Then we made all the Sail we could for the Island again. The 30th Day we had the Wind at West, and saw the Islands. * * * * This last Storm put our Men quite out of heart: for although it was not altogether so fierce as that which we were in on the Coast of *China*, which was still fresh in Memory, yet it wrought more powerfully, and frighted them from their Design of cruizing before *Manila*, fearing another Storm there." (See DAMPIER'S "*New Voyage Round the World*." Chap. XV. p. 413—416, also p. 437—439: ed. 1697.)

It may not be amiss to notice that DAMPIER gives an excellent account of the Monsoons of the Malabar and Coromandel coasts, of the period of change of those winds, and of the storms then prevalent; it is also not improbable that he encountered a cyclone, May 1688, between the Nicobars and Sumatra. Though he never experienced a hurricane during his stay among the West Indian islands, he describes one, from hearsay; how "the wind came on very fierce at N.E. and veering about to N. and N.W. settled there, bringing with it very violent Rains;" how it subsequently "fell flat calm, and the Rain ceased;" how, during the calm, the men went down to the ships and found them high and dry, and how they made haste back "because the Wind began to blow hard at S.W., and it blew so violently before they recover'd the House, that the Boughs of the Trees whipt them sufficiently before they got thither; and it rained as hard as before;" that "when the N.E. Gust raged, the Sea ebb'd so prodigiously, or else was driven off the shore by the violence of the Wind so far, that some Ships riding in the Harbour in 3 or 4 fathom Water, were a-ground, and lay so till the S.W. Gust came, and then the Sea came rowling in again with such prodigious fury, that it not only set them a-float, but dash'd many of them on the shore." The narrative relates to Muskito cove, St. John's harbour, Antigua, in August, 1681; and he informs us that the island suffered as well as the ships, houses being blown down and trees uprooted, so that all looked like winter; "neither did the fury of this Storm light only here, for *Nevis* and *St. Christophers* had their shares also; but *Mountsurat* felt little of it." He does not forget to mention that these violent storms rage "chiefly among the *Carribee Islands*, though by Relation *Jamaica* is annoyed by them," and that "they are expected in *July*, *August*, or *September*." After giving a long account of the Northers and the Souths of the Gulf of Mexico and Carribean Sea, he concludes as follows:—"the Clouds that precede a Hurricane are different from the North Banks, in this, that whereas the Clouds preceding Norths are uniform and regular; of an exact blackness even from the Horizon to the upper edge of it, and that as streight and even as a Line stretched out. On the contrary, the Hurricane-Clouds tower up their Heads, pressing forwards as if they all strove for precedency; yet so linked one within another, that all move alike. Besides, the edges of these Clouds are guilded with various and affrighting Colours, the very edge of all seems to be of a pale fire colour, next that of a dull yellow, and nearer the Body of the Cloud of a Copper Colour, and the Body of the Cloud which is very thick appears extraordinary Black: and altogether it looks very terrible and amazing even beyond expression. Tho' I have never been in any Hurricane in the *West Indies*, yet I have seen the very Image of them in the *East Indies*, and the effects have been the very same; and for my part I know no difference between a Hurricane among the Carribee Islands in the *West Indies*, and a Tuffoon on the Coast of *China* in the *East Indies*, but only the Name: And I am apt to believe that both Words have one signification, which is a *violent Storm*." (DAMPIER'S *Voyages and Descriptions*, Vol. II., part III.)

During the 17th and 18th centuries descriptions of the West Indian hurricanes become numerous: the writers are chiefly English, Spanish, and French; and in various "dissertations on winds," "theories of the winds," and "causes of hurricanes," appear many "new hypotheses,"—such as the effect of lunar, magnetic or electric influence, &c. The veering of the wind in a hurricane came, however, to be a recognised fact. A Capt. LANGFORD has a paper in the *Philosophical Transactions*, 1698, on West Indian hurricanes and their prognostics, in which he repeatedly refers to them as "whirlwinds," states how the winds veer, but evidently misapprehended their progression; and Sir GILBERT BLANE, describing (Edinburgh *Phil. Trans.* 1788) the Barbados hurricane of Oct. 10, 1780, observes that "the wind blew all round the compass, a circumstance which distinguishes the hurricane from all other gales within the tropics."

We now arrive at the 19th century, prior to which it cannot be said that there was any investigation (properly so to speak) into the physical character of these tropical storms, nor any generalization of facts.

In 1801 Colonel JAMES CAPPER published his *Observations on Winds and Monsoons*, in which work, speaking of the "tremendous gales or rather hurricanes" that blow, after the change of the monsoons, on the Malabar and Coromandel coasts and in the Bay of Bengal, he states that "all the circumstances properly considered, clearly manifest the nature of these winds, or rather positively prove them to be whirlwinds;" he indicates their probable size, their localities, and their seasons, referring at the same time to the hurricane season at Mauritius and the West Indies. But what is more significant than all he indistinctly sees that his investigations might have a practical application;—"It would not perhaps be a matter of great difficulty to ascertain the situation of a ship in a whirlwind by observing the strength and changes of the wind. If the changes are sudden and the wind violent, in all probability the ship must be near the centre or vortex of the whirlwind; whereas, if the wind blows a great length of time from the same point, and the changes are gradual, it may be reasonably supposed the ship is near the extremity of it."

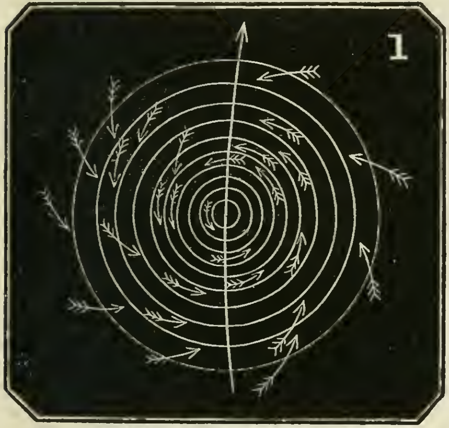
HORSBURGH, so well known to seamen by his "*Directory*," published, in 1805, *Memoirs comprising the Navigation to and from China by the China Sea*, in which he gives a long account of the Ty-foongs; he speaks of their "*rotary*" motion, describes the veering of the wind according to their direction, notes the characteristics of their approach, and advises the navigator how to manœuvre when overtaken in such storms.

ROMME in his *Tableau des Vents*, published in 1806, describes the hurricanes and whirlwinds of the West Indies and Mexico, the tempests of the Mozambique Channel and the Bay of Bengal, and the Tyfoons of China, &c.; he notes the veering of the wind, and the whirlwinds (tourbillons) of those regions, with their characteristic high sea, cloudy sky, and heavy rain.

Professor FARRAR, of Cambridge University, U. S., when describing the storm that passed over Boston on Sept. 23, 1815, though unable "to find the centre, or limits of this tempest," estimates it at about 200 miles in diameter; remarks that "it was very violent at places separated by a considerable interval from each other, while the intermediate region suffered much less;" and comes to the conclusion that it was "a moving vortex and not the rushing forward of the great body of the atmosphere."

About this period every storm of greater violence than usual had its historian, and speculations on the cause and physical character of the phenomena were as conflicting as numerous. There were writers on the subject in England, France, Germany and the United States: some describe, with considerable accuracy, the prognostics of hurricanes, and their seasons; others notice their progression in particular directions; later on, a few infer, like Professor E. MITCHELL in his *Proximate Cause of Certain Winds* (1831), that "the phenomena of winds and storms are the result of a vortex or gyratory movement * * * in the region of the atmosphere where they prevail;" the great and rapid oscillations of the barometer during a hurricane had come to be a matter of frequent and special remark; while of theories respecting the origin of these tempests, the electrical one, as in the case of tornadoes and waterspouts, was most in favour.

As yet, however, nothing very definite or satisfactory had been done towards elucidating the real character of hurricanes. That could only be accomplished, as we now fully appreciate, by a close investigation of numerous simultaneous observations extending over a wide area: this was clearly perceived by the late WILLIAM C. REDFIELD, a Naval Architect in the United States, who published his first paper—*Remarks on the Prevailing Storms of the Atlantic Coast of the North American States*— in 1831; but if report is correct, he had been engaged on the study of the subject since 1821—a period of ten years. The conclusions at which he arrived were the product of continuous observation combined with experiment; when a hurricane occured he collected whatever information was to be obtained respecting it in its passage along the coast and through the country, and for the oceanic area he procured extracts from the log-books of ships that had been involved in it; the mass of facts was at first a source of much thought and speculation; eventually, having plotted on a chart of large scale the direction of the winds observed at given positions on the same day and about the same hour—in fact, a series of nearly simultaneous observations made far and wide—he adopted a tentative process, and found that by placing on this chart a transparency (tracing paper) marked in concentric circles, the majority of the wind-arrows (for a given day) were closely coincident with these circles (*see* Fig. 1); trial after trial gave the same result, and he then became convinced that the mass of air constituting the hurricane had a rotatory movement around a central calm. The experiment similarly tried at another spot for the following day, and so on for successive days at different spots, showed also that the storm-field was not stationary, but that it moved bodily forward. It was on the basis of these empirical investigations that REDFIELD announced, in 1831, that the winds constituting a hurricane had a rotatory movement (*i. e.* blowing around a common centre) while the storm itself had a progressive motion; and this was the foundation of the "*Law of Storms.*"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REDFIELD's views are fully embodied in a paper, published in 1833, and entitled *Observations on the Hurricanes and Storms of the West Indies and the Coast of the United States*, a portion of which it may not be amiss to introduce here:—

"From a careful attention to the progress and phenomena of some of the more violent storms which have visited the Western Atlantic, I have found that they exhibit certain characteristics of great uniformity. This appears, not only in the terminate course which these storms are found to pursue, but in the direction of wind and succession of changes which they exhibit while they continue in action. The same general characteristics appear also to pertain, in some degree, to many of the more common variations and vicissitudes of winds and weather, at least in the temperate latitudes. The following points I consider as established:

"1. The storms of greatest severity often originate in the tropical latitudes, and, not unfrequently, to the Eastward of the West India Islands; in the tropical regions they are distinguished by the name of *hurricanes*.

"2. These storms cover, at the same moment of time, an extent of contiguous surface, the diameter of which may vary, in different storms, from 100 to 500 miles, and in some cases they have been much more extensive. They act with diminished violence towards the exterior, and with increased energy towards the interior, of the space which they occupy.

"3. While in the tropical latitudes, or South of the parallel of 30° N., these storms pursue their course, or are *drifted* by the natural atmospheric current of the region towards the West, on a track which inclines gradually to the Northward, till it approaches the latitude of 30° N. In the vicinity of this parallel, their course is changed somewhat abruptly to the Northward and Eastward, and the track continues to incline gradually to the East, towards which point, after leaving the lower latitudes, they are found to progress with an accelerated velocity.

"The rate at which these storms are found thus to advance in their course, varies in different cases, but may be estimated at from 12 to 30 miles an hour. The extent to which their course is finally pursued, remains unknown: but it is probable that, as they proceed, they become gradually extended in their dimensions, and weakened in their action, till they cease to command any peculiar notice. One of the hurricanes of August, 1830, has been traced in its daily progress, from near the Caribbee Islands to the coast of Florida and the Carolinas, and thence to the banks of Newfoundland, a distance of more than 3,000 miles, which was passed over by the storm in about six days. The duration of the most violent portion of this gale, at the different points over which it passed, was about 12 hours, but its entire duration was, in many places, more than twice that period. Anothur hurricane which occurred in the same month, passed from near the Windward Islands, on a more Eastern but similar route, and has also been traced in its daily stages by means of the journals and reports of voyages, near 2,500 miles. The hurricane of August, 1831, which desolated the Island of Barbadoes on the 10th of that month, the daily progress of which has also been ascertained, passed in nearly a direct course to the Northern shores of the Gulf of Mexico and New Orleans, where it arrived on the 16th of the same month, having passed over a distance of 2,300 statute miles in six days after leaving Barbadoes. Many cases of like character might be adduced.

"4. The duration of the storm, at any place within its track, depends upon its extent and the rate of its progressive velocity, as these circumstances are found to determine the time which is required for the storm to pass over any given locality falling within its route. Storms of smaller extent or dimensions are usually found to move from one place to another with greater rapidity than larger storms.

"5. The course thus pursued by the storm, is found to be entirely independent of the direction of wind which it may exhibit at the different points over which it passes—the wind in all such storms being found to blow after the manner of a whirlwind, around a common centre or vortex, during their entire progress, and in a determinate direction or course of rotation, which is from *right to left* (or in the direction from West to South) horizontally. The direction of the wind, therefore, for the most part, does not coincide with the course of the storm.

"6. In the lower latitudes, while drifting to the Westward, the direction of the wind at the commencement, or under the most advanced portion of these storms, is from a *Northern* quarter, usually at some point from North-east to North-west, and during the latter part of the gale, it blows from a Southern quarter of the horizon, at all places where the whole effect of the gale is experienced.

"7. After reaching the more Northern latitudes, and while pursuing their course to the Northward and Eastward, these storms commence with the wind from an Eastern or Southern quarter, and terminate with the wind from a Western quarter, as will appear more distinctly under the three following heads, the latter portion of the storm being usually attended with broken or clear weather.

"8. On the outer portion of the track, North of the parallel of 30° N., or within that portion of it which lies *furthest* from the American coast, these storms exhibit at their commencement a *Southerly* wind, which as the storm comes over, *veers gradually to the Westward*, in which quarter it is found to terminate.

"9. In the same latitudes, but along the *central portion of the track*, the first force of the wind is from a point near to *South-east*, but after blowing for a certain period it *changes suddenly*, and usually after a short intermission, to a point nearly or directly opposite to that from which it has previously been blowing, from which opposite quarter it blows with equal violence till the storm has passed over, or has abated. This sudden change of a South-easterly wind to an opposite direction, *does not occur towards either margin of the storm's track*, but only on its more central portion, and takes effect in regular progression along this central part of the route, from the *South-west* towards the *North-east*, in an order of time which is exactly coincident with the progress of the storm in the same direction. It is under this portion of the storm that we notice the greatest fall of the barometer, and the mercury usually begins to rise a short time previous to the change of wind. In this part of the track the storm is known as a *South-easter*, and is usually attended with rain previous to the change of wind, and perhaps for a short time after.

"10. On that portion of the track which is *nearest* the American coast, or which is furthest inland if the storm reaches the continent, the wind commences from a more Eastern or North-eastern point of the horizon, and afterwards veers more or less gradually, by North, to a North-western or Westerly quarter, where it finally terminates. Here also the first part of the storm is usually, but not always, attended with rain, and its latter or Western portion with fair weather. The first or foul-weather portion of the storm is, on this part of its track, recognized as a *North-easter*.

"It should be noted, however, that near the latitude of 30° N., and on the shores of Carolina, where the storm enters obliquely upon the coast, while its track is rapidly changing from a Northwardly to an Eastwardly direction, the wind on the central track of the storm will commence from an Eastern or North-eastern point of the compass, and will gradually become South-easterly as the storm approaches its height.

"11. A full and just consideration of the facts which have been stated, will show conclusively that the portion of the atmosphere which composes for the time being the great body of the storm, whirls or blows as above stated, in a horizontal circuit, around a vertical or somewhat inclined axis of rotation which is carried onward with the storm; that the course or direction of this circuit of rotation is from *right to left*; and that the storm operates nearly in the same manner as a tornado or whirlwind of smaller dimensions; the chief difference being in the more disc-like form of the whirling body and the magnitude of the scale of operation.* This view of the subject, when fully comprehended, affords a satisfactory solution of the otherwise inexplicable phenomena of storms, and will also be found to accord entirely with the fact which appears in the above statement, that in the phases or changes which pertain to a storm, the wind, on one margin of its track, veers *with the sun*, or from *left to right;* while under the opposite margin of the same storm it veers *against the sun*, or from *right to left;* for this peculiarity necessarily attends the progressive action of any whirlwind which operates horizontally.

"12. Owing to the centrifugal action of these rotative storms, the barometer, whether in the higher or lower latitudes, always sinks while under the first portion or moiety of the storm on every part of its track, excepting, perhaps, its extreme outward margin, and commonly affords us the earliest and surest indication of the approaching tempest. The mercury in the barometer always rises again during the passage of the last portion of the gale, and commonly attains the maximum of its elevations on the entire departure of the storm.

"The great value of the barometer to navigators is becoming well understood, and its practical utility might be greatly increased by hourly entries of the precise height of the mercurial column, in a table prepared for the purpose. Its movements, unless carefully recorded, often escape notice or recollection; which may easily happen at those times when a distinct knowledge of its latest variations might prove to be of the greatest importance.

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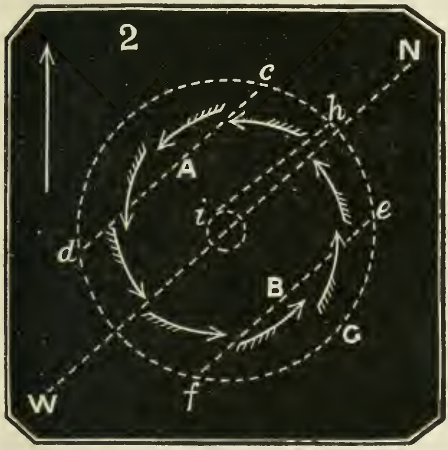
* It is to be understood that the diameter of the whirlwind which constitutes the storm is commensurate with the width of the track over which the storm passes. The main body of the storm is supposed to move in the form of an extensive disc, whirling around its own centre as it advances in its regular track—with this difference, that the rotative movement is far more rapid in the interior portions of the whirling body, than towards its exterior limits.

"In the foregoing statements our design has been to designate in a summary manner the principal movements which, in these regions at least constitute a storm; and we do not attempt to notice the various irregularities, and subordinate or incidental movements and phenomena of the atmosphere with which a storm may chance to be connected, or which may necessarily result from such violent movements in a fluid which is so tenuous and elastic in its character. It may be remarked in general, that the most active or violent storms are usually the most regular and uniform in the development of those characteristic movements which we have already described. It is also probable that the vortex or rotative axis of a violent gale or hurricane, oscillates in its course with considerable rapidity, in a moving circuit of moderate extent, near the centre of the hurricane; and such an eccentric movement of the vortex may, for aught we know, be essential to the continued activity or force of the hurricane. Such a movement will fully account for the violent *flaws* or *gusts* of wind, and the intervening *lulls* or remissions, which are so often experienced towards the heart of a storm or hurricane, when in open sea; but of its existence we have no positive evidence.

"It has been stated, 'that while one vessel has been lying to in a heavy gale of wind, another, not more than 30 leagues distant, has at the very same time been in another gale equally heavy, and lying to with the wind in quite an opposite direction.'

"This statement is obviously to be understood as applicable to two vessels falling under the two opposite sides or portions of the same storm, where the wind in its regular circuit of rotation must, of course, blow from the opposite quarters of the horizon. We will suppose one of the vessels to be at A and the other at B, in the annexed figure. The storm, in pursuing its course from W. towards N., will strike the first-mentioned vessel in the direction which is shown by the wind-arrows at the point *c*, which, if the position be in the temperate latitudes, North of 30°, will be from Eastward. Now, it is obvious, that as the storm advances in its course North-eastward, this vessel, if nearly stationary, will intersect the body of the gale on the line *c* A *d*. As the storm advances, the wind must also veer to the Northward, as shown by the arrows, being at N.E. when the vessel is brought under the point A; and near the close or departure of the



storm by its further progress Eastward, the wind will have further veered to the direction shown at *d*, which, with due allowance for the progressive motion of the storm, we will set down at N.N.W. The other vessel, as is equally obvious, will first take the wind from the Southward, as shown at *e*, in which quarter it will blow, with no great variation, till, by the advance of the storm, the ship is brought under the point B. The barometer, which had previously been falling, will now commence rising, and the wind, veering more Westerly, will, at the departure of the storm, be found in the direction shown at *f*, which, after the allowance already referred to, may be stated at W.N.W. Such, substantially, are the facts commonly reported by vessels which fall under the lateral portions of the Atlantic storms; and it is readily seen that the opposite winds which are exhibited on the two different intersections of the storm, as above described, will very naturally be mistaken for two separate and distinct gales.

"The phases of the wind in these gales are, however, in all cases modified more or less by the course or changing position of the vessel exposed to its action. For example: a ship on taking the gale, say at E.S.E., at the point *h* on the figure, and lying to with her head to the Northward, may by that means be brought to intersect the storm on the line *hi*, and at the point *i* would suddenly be taken aback, with the wind, say at N.N.W., as in the case of the Jamaica homeward-bound fleet in 1782; and the barometer, which reaches its lowest depression under the central portion of the storm, would about this period be found to have commenced rising with some degree of rapidity.

"A further reference to the figure will show that a ship, which may be at the point G during the passage of the gale, would be exposed to a heavy swell from the Southward and Westward; but, being beyond the organized limits of the storm, may remain entirely unaffected by the violence of the wind, which at the same time may be raging with destructive fury at the distance of a few leagues. The writer has knowledge of many such examples.

"It has been suggested that the 'port tack is the proper one to lie to on, as the wind will then be found to draw aft;' but this will frequently prove erroneous, as the wind may draw either way, on either tack, according to the position and course of the ship, in the storm, and the extent and rate of progress of the latter. In the case of the fleet which encountered the gale of 1782, it was probably the best course to carry sail to the Northward at the very commencement of the gale, and as far and as long as possible. By this means the fleet might, perhaps, have been drawn as far Northward as the point A on the figure, and the change of wind to the Northward and Westward would have been rendered more gradual. The chief difficulty and danger is, when the direction of the wind, at the first setting in of the gale, is found to be nearly at right angles with the known course of the storms in the region where the gale is encountered, and it is then desirable to pursue such a course as to avoid, if possible, falling into the heart of the storm.

"It frequently happens that a storm, during the first part of its progress over a given point, fails to take effect upon the surface, while it exhibits its full activity at a greater altitude. This commonly happens when this portion of the storm arrives from, or has recently blown over a more elevated country, or is passing or blowing from the land to the sea. On land, the most violent effects are usually felt from those storms which enter and blow from the open ocean upon the shores of an island or continent. Upon the latter, under such circumstances, the *first* part of the gale is usually the most severe, and that coast of an island upon which a storm first enters, or blows, also suffers most from the early part of the gale; but its later, or receding part, often acts with the greatest fury upon the opposite side of the island, which had previously derived some degree of shelter from the intermediate elevations and other obstacles opposed to the force of the wind, the benefit of which is now lost by its counter-direction from the open ocean. Owing to similar causes, the force of the storm is sometimes very unequal at different places, situated in nearly the same part of its track, and such inequality as we have before intimated, necessarily pertains to two places, one of which is near the centre and the other towards the margin of the route."

The remarks are accompanied by the tracks of eleven West Indian hurricanes, and he observes further;—

"The dimensions of these storms appear to gradually expand during their course. * * * The track of most hurricanes appear to form part of an elliptical or parabolic circuit. We are also struck with the fact that the vortex of the curve is uniformly found on or near the 30th degree of latitude.

"The typhoons and storms of the China Sea and Eastern coast of Asia, appear to be similar in character to the hurricanes of the West Indies and the storms of this (American) coast when prevailing in the same latitudes. There is reason to believe that the great circuit of wind, of which the Trade Winds form an integral part, are nearly uniform in all the great oceanic basins; and that the *course* of these circuits and of the stormy gyrations which they may contain, is in the Southern hemisphere, in a *counter-direction* to those North of the equator, producing a corresponding difference in the general phases of storms and winds in the two hemispheres."*

The *Law of Storms* as thus developed by REDFIELD was not, however, permitted to pass unchallenged; but his chief opponents were his own countrymen, and to these it will be necessary to refer in the sequel.

While REDFIELD was busy in America there were active enquirers in the field of research in Europe, and the first important work published on the subject in England was by Lieut.-Col. W. REID, in 1838,—*An*

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* REDFIELD, although he never published a separate work on the law of storms and its application, was a frequent contributor to various Magazines and to the *Proceedings of the American Society for the Advancement of Science.* These memoirs and papers amount in number to thirty-three; his last observations were on the "Cyclones of the Western Pacific," written for Admiral PERRY's *Japan Expedition,* shortly before his death in 1857.

Attempt to develop the Laws of Storms by means of Facts, arranged according to Place and Time, &c.,— a third edition of which appeared in 1850.

As governor of the Bermudas, Col. (afterwards Sir W.) REID was well placed for personal observations and investigation, as the islands lie in the track of hurricanes. He not only confirmed REDFIELD'S views—that those storms in the northern hemisphere are vast whirlwinds with a progressive motion, revolving by a fixed law, — but, by collecting information concerning the Mauritius gales, he proved that they revolve in opposite ways on opposite sides of the Equator, thus also corroborating what REDFIELD had already announced as probable. It may be said, without any undervaluing of the labours of others, that most of the really useful *practical rules* in storm-sailing are due to REID, and that he never lost sight of the *practical application of the subject to navigation.* Besides reports and papers in various Journals, he published, in 1849, a work on the *Progress of the Development of the Law of Storms, and of Variable Winds.*

HENRY PIDDINGTON, late President of the Calcutta Marine Courts, and so well known to seamen by the *Sailor's Horn-Book for the Law of Storms*, appeared in the field in 1840: he was a careful observer, and an indefatigable collector of facts respecting hurricanes; in addition to twenty-four memoirs published in the *Jour. Asiatic Soc. of Bengal*, he wrote several pamphlets and short papers. He was a follower of REDFIELD and REID, but was more popular than either,—perhaps from collating his material better, and being on the whole more discursive.

Another observer and writer must not be omitted; ALEXANDER THOM, Surgeon, when stationed with his regiment at Mauritius, gathered the materials for an *Inquiry into the Nature and Course of Storms in the Indian Ocean south of the Equator*, which was published in 1845; while agreeing, in the main, with REDFIELD and REID on the law of storms, and the practical rules laid down by the latter, he entirely differs from PIDDINGTON in his theory. It may, however, be stated that, on the whole, the four writers are more practical than theoretical. It is unnecessary to refer at present to the views of later meteorologists.

REDFIELD undoubtedly arrived at his results by an independent course of investigation; but another was at work at the same time in the same direction. Professor H. W. DOVE, of Berlin, in an article on *Barometric minima*, published in 1828, had come to the conclusion that hurricanes, accompanied by great depressions of the barometric column, are vast whirlwinds moving, in the northern hemisphere, from S.W. to N.E.,—and on this basis claimed priority of discovery of the Law of Storms.

From a practical point of view, however, REDFIELD was unquestionable first in the field. On the other hand, to DOVE belongs the merit of having been the first to expound and elucidate the *rotatory theory on the principle that it is the simple and necessary consequence of the earth's rotation:* this he fully developed in his important work, *Das Gesetz der Stürme* (*the Law of Storms*), extracts from which—in so far as they immediately relate to, and have a direct practical bearing, on the subject—may be appropriately condensed into a few pages:—

The earth is a globe turning on its axis from West to East, and the velocity of rotation at different places on the surface varies as the diameter of the parallels on which the places are situated; thus this velocity increases from *zero* at the *poles* to its *maximum* at the *equator*.* Now the air, even when apparently motionless, partakes of the velocity of rotation of the part of the globe over which it rests: hence, if a difference of temperature, or any other cause, gives it a tendency to move in a direction along a parallel, its motion cannot be affected by the earth's rotation, because the points on the earth's surface towards which it is moving have exactly the same velocity of rotation as those which it has left. If, however, through any cause, the air is set in motion from the poles towards the equator, it passes from places with less, to others with greater, rotatory velocity; and consequently having less velocity towards the East than the places at which it arrives, it appears to be moving in the contrary direction, viz. from East to West.

The deviation of the wind from its direction at starting, supposing its rate of progression to remain unaltered, will be greater, the greater the difference between the velocity of rotation of the point whence the wind set out and that where it is observed; or in other words, the greater the difference of latitude between the two places. From this it results that—

1. In the northern hemisphere winds, which at starting are North, change gradually, through N.E., towards East.

2. In the southern hemisphere winds, which at starting are South, change gradually, through S.E., towards East.

3. In the northern hemisphere a southerly wind, in its progression, gradually veers through S.W. towards West.

4. In the southern hemisphere a northerly wind, in its progression, gradually veers through N.W. towards West.

A West wind in both hemispheres will interfere with fresh equatorial currents, and bring them to a state of relative rest. If the tendency *towards* the pole continues, the same thing will always be repeated, until fresh polar currents change the West wind in the northern hemisphere, through N.W. into North,—and in the southern hemisphere, through S.W. into South. This gives—

For the northern hemisphere, the change through S., S.W., W., N.W., N.

For the southern hemisphere, the change through N., N.W., W., S.W., S.

And hence the following results may be deduced:—

(A) In the northern hemisphere, when polar and equatorial currents alternately succeed each other, the wind veers in general round the compass in the direction

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* The rotatory velocity of a place on the Equator is 15 geog. miles per minute; in lat. 45°, it is 10½ miles; in lat. 51½° about 9¼ miles; in lat. 60° about 7½ miles; and in lat. 70° about 5 miles.

→ S., S.W., W., N.W., N., N.E., E., S.E., S. →

and the change takes place oftener between S. and W., and between N. and E., than between W. and N., and between E. and S.

(B) In the southern hemisphere, when polar and equatorial currents alternately succeed each other, the wind veers in general round the compass in the direction

→ S., S.E., E., N.E., N., N.W., W., S.W., S. →

and the change takes place oftener between N. and W., and between S. and E., than between W. and S., and between E. and N.

This is Dove's "Law of Gyration" (Gesetz der Drehung), or the *Law of the Rotation of the Winds.*

According to this law, the *veering* of the wind-vane may merely indicate the existence of a steady current of air; and it is a misapprehension of this fact that causes the existing, or constantly recurring, confusion with reference to questions bearing on the theory of the winds. The essential difference between the veering of the wind-vane as produced by a steady breeze and that resulting from a centripetal current, or a whirling motion with an advancing centre, is, however, that in the first case (*i.e.* with a steady breeze) the rotation is always in the same direction, but in the case of the second (*i.e.* in a whirlwind or hurricane) it veers on both sides of the track and in opposite directions.

If, therefore, as regards the *Northern Hemisphere,* the veering in the direction S., W., N., E. be called "with the sun" or *direct,* and the veering in the direction S., E., N., W. be called "against the sun," or *retrograde,* as is customary: and similarly, in the *Southern Hemisphere,* the veering through S., E., N., W. be called "with the sun,"* and the veering through S., W., N., E. be called "against the sun,"* it follows that—

Steady winds turn the vane only in a *direct* sense, that is *with the sun.*

Whirlwinds, or centripetal gales, if they have a progressive motion, turn the vane either with or against the sun, according to the side on which the centre passes the place of observation. Finally—

When steady winds from different directions approach each other, rotations ensue in both ways;—*direct* when, on the *west* side of the compass, a wind is more northerly than that which preceded it,—

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* These expressions differ from the seaman's view: the movement *from left to right,* as being "with the sun," originated in the *northern* hemisphere, beyond the tropic, where the sun culminates in the South, and hence, looking in that direction, the sun rises on the left, and sets on the right, hand—i.e. *left to right,* "with the sun;" this idea the seaman carries with him over every part of the globe. But, left to right, "with the sun," is erroneous in the southern hemisphere, where an observer sees the sun rise on the right hand, culminate in the North, and set on the left hand. The expression in the text is therefore correct, though not in the seaman's sense.

retrograde, when it is more southerly. On the *east* side, on the contrary, the gyration is *direct* when the displacing wind is more southerly than that which preceded it,—*retrograde*, when it is more northerly. Winds from directly opposite points may check each other and produce a calm, and thereby give rise to the same phenomenon as is observed at the centre of a series of centripetal currents or of a whirlwind, *viz.* winds diametrically opposed separated by a calm.

Thus the same appearances may arise under totally different conditions, and it is only by means of a careful investigation of all the phases of a phenomenon that a decision can be pronounced on any one phase which presents itself in a particular instance. In these researches the *barometer* is one of the chief guides.

The following brief remarks (p. 19—26) are a general summary of the result of Dove's investigations into the *Law of the Rotation of the Winds and the Law of Storms**:—

(1.) All steady winds are modified by the earth's rotation in such manner that equatorial currents receive a westerly deflection, and polar currents an easterly deflection.

The N.E. and the S.E. Trade-winds are *steady* polar currents.

The Monsoons are *alternations* of a polar and equatorial current according to the season of the year,—therefore, they are N.E. and S.W. in the northern hemisphere, and S.E. and N.W. in the southern hemisphere.

(2.) Bodies of air which, from a state of rest, are set in motion in the direction of the meridian, turn the wind-vane as follows:—

The polar current in the northern hemisphere, from N. to E.

The polar current in the southern hemisphere, from S. to E.

The equatorial current in the northern hemisphere, from S. to W.

The equatorial current in the southern hemisphere, from N. to W.

Hence, generally, in the *northern hemisphere*:—

Winds between N. and E. are the polar current,—and

Those between E. and S. mark the transition of the polar into an equatorial current:

Winds between S. and W. are the equatorial current,—and

Those between W. and N. mark the transition of the equatorial into a polar current.

In the *southern hemisphere*:—

Winds between S. and E. are the polar current,—and

Those between E. and N. mark the transition of the polar into an equatorial current:

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* "Das Gesetz der Stürme," p. 187—192.

Winds between N. and W. are the equatorial current,—and
Those between W. and S. mark the transition of the equatorial into a polar current.

Thus, a complete rotation in the *northern* hemisphere is—

➳ S., W., N., E., S. ➳ with the sun;

And in the *southern* hemisphere—

➳ S., E., N., W., S. ➳ with the sun.

(3.) The course of a steady wind may be obstructed from following the deflection impressed on it by the rotation of the earth :—

(*a*) By a wind blowing constantly in a direction perpendicular to its primitive: such are the West-Indian hurricanes, which, for this reason, advance first from S.E. to N.W.; while those of the southern hemisphere advance from N.E. to S.W.

(*b*) By a less deflected aërial current; such is the origin of typhoons during the S.W. monsoon which, farther to the eastward, is bounded by the South monsoon. Of the typhoons, however, that have a progressive motion from W. to E., it is probable that they result from the heavy air of the Trade-wind region—situated to the eastward—rushing laterally through the rarefied air of the region of the S.W. monsoon, and thus producing a whirlwind.

(*c*) By a mechanical impediment; as in the instance of a storm (described by PIDDINGTON) which occurred in the Bay of Bengal, June, 1839.*

In these cases, when the storm is an equatorial one, whirlwinds are produced in the *northern* hemisphere in a *direction contrary to that in which the hands of a watch move:* and in the *southern* hemisphere in the *same direction as the hands of a watch move.*

Hence in the *northern* hemisphere the following shiftings of the wind-vane occur :—

(*a*) If the centre of the storm passes westward of the place of observation—

The rotation will be ➳ S., W., N., E., S. ➳ with the sun;

(*b*) If the centre of the storm passes eastward of the place—
The rotation will be ➳ S., E., N., W., S. ➳ against the sun.

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* When a strong Monsoon wind, "blowing in with tolerable steadiness from one quarter of the compass," was diverted from its course by the mountains of Arracan, and became "a hurricane, *i.e.* a violent wind blowing in a circle or vortex of greater or less diameter."

But, in the *southern* hemisphere, on the contrary, when the storm is an equatorial one:—

(*a*) If the centre of the storm passes westward of the place of observation—

The rotation will be ⟶ S., E., N., W., S. ⟶ with the sun;

(*b*) If it passes eastward of the place—

The rotation will be ⟶ S., W., N., E., S. ⟶ against the sun.

Thus, in both hemispheres, an *Equatorial* whirlwind-storm passing on the west side of the place of observation produces *normal* rotations, *i.e.* such as are in accordance with the law of gyration; but its passage on the east side of the same place produces *anomalous* rotations, *i.e.* such as are contrary to the law of gyration. In *Polar* whirlwind-storms the effect is precisely opposite to that just described:—the rotation is normal when the centre passes to the eastward, and anomalous when it passes to the westward, of the place of observation.

The old rule that "anomalous shiftings of the wind-vane occur in stormy weather" is in this manner justified. It cannot, however, be ascertained from those shiftings whether an equatorial whirlwind passes on one side, or a polar one on the other; this depends on the initial point of the shifting, and, as a consequence of the rotation, can never amount to more than half a circle.

(4.) The wind-vane may shift from one direction to that immediately opposite to it:—

(*a*) When steady winds oppose each other; *i.e.* fight with each other, as the seaman says; and

(*b*) When the centre of a whirlwind-storm passes over the place of observation.

(5.) A wind may be part of a whirlwind storm even when the wind-vane does not shift at the place of observation. This happens when the place is so situated as to be only on the *outer edge* of the whirlwind. On one side the storm then appears to retrograde,—and on the other to advance:—if, for instance, a whirlwind (revolving contrary to the motion of watch-hands) is advancing from S.W. to N.E., on the north-west side of such a storm, a N.E. wind is experienced in the south-westerly regions *earlier* than in the north-easterly, whilst on the south-east side of the storm a S.W. wind actually appears to be advancing, and so it enters the north-easterly regions at a later period. The first is the well-known case observed (in 1742) by FRANKLIN during an eclipse of the moon.* Those who, founding their theory on this and analogous instances, divide the winds into positive (*by aspiration*), and negative (*by impulsion*), call one side of such a storm positive and the other negative.

(6.) In the temperate zones storms are caused, also, by two oppositely directed currents of air in juxtaposition—one pressing laterally on the other; then, during the transition, the shifting of the wind-vane may be either with or against the sun, but always according to the direction of one or other of the currents impinging on each other.

(7.) Local phenomena, as land and sea breezes, counter currents through valleys, deflections of the trade-winds by the coast, *trombs*,† &c., affect the wind-vane according to local conditions, and these may be such as either to produce a veering of the vane in accordance with, or contrary to, the law of rotation. In open regions this occurs periodically every day, at the season when the general air-currents (trades) are less predominant,—as is the case also in the region of the "*variables*" between the trades,—at the time of the change of the monsoons,—and generally in summer, when the ascending current (*courant ascendant*) weakens the force of the horizontal currents. Indeed, it is not impossible that, setting aside local influences, one cause of a periodical shifting of the wind-vane originates in the daily course of the sun; for example, if the locality where the daily maximum of temperature occurs forms *a point of attraction* for bodies of air in its vicinity, then will the direction of the wind during the *morning* be *westerly*, and during the *afternoon*, *easterly*,—and thus the wind-vane will turn in a direction contrary to the movement of the magnetic needle.

Now whirlwinds not being confined to a definite locality, the probability that any given place may be situated on the east side of their course is just as great as that it should be on the west side; the same is also the case where whirlwinds owe their origin to local causes. The predominance of the rotation of the wind in a definite direction (with the sun) is consequently a phenomenon unconnected with the whirling motion of the storm-winds, but due only to the influence of the earth's rotation on progressive steady winds.

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* This was the hurricane of Oct. 21, 1742: FRANKLIN, at Philadelphia, was unable to observe the eclipse of the moon that occurred that evening, but it was seen at Boston. The N.W. side of the storm, with its N.E. wind, reached Philadelphia about 7 p.m., and *subsequently* (at 11 p.m.) appeared at Boston, about 400 miles N.E. of the former place.

† It has been observed that *trombs*, or small local whirlwinds, being due to local causes and not being affected by the earth's rotation, *turn indiscriminately, some one way and some the other, and depend on no rule producing uniformity of motion.*

Now three things are possible :—

1. Either all rotations of the wind-vane through great arcs are caused by whirlwinds ; and in this case,—
    (*a*) If these whirlwinds occur arbitrarily, now at one place and then at another, there is no predominating direction in the shifting of the vane;—or,
    (*b*) If the origin of these whirlwinds is local, and if, in their progress, they pursue paths more or less constant, then there are, at certain places in each hemisphere, predominant shiftings of the wind-vane in the direction S., E., N., W., and at others, in the direction S., W., N., E.
2. Or, all shiftings of the wind-vane have their origin in alternations or displacements of steady meridional air-currents, in accordance with the principles of Hadley's theory of the trade-winds, and in consequence of opposing currents pushing through each other: in this case the rotation is in the direction S., E., N., W. in the northern hemisphere,—and S., W., N., E. in the southern hemisphere,—*i.e.* in *both* cases the *wind veers with the sun.* The backing of the wind cannot under these conditions exceed a quadrant of the circle.
3. Or, lastly, the shiftings of the wind-vane arise in both ways, viz.—from the alternation and displacement of meridional air-currents, *and*, from a progressive whirlwind; consequently, in each hemisphere, rotations of both kinds must occur, but those "with the sun" will predominate. In both hemispheres, the first cause produces only rotations with the sun, and the second produces just as many rotations with the sun as against the sun. Hence (however frequent whirlwinds may be) the rotations that are direct must always be in excess of those that are retrograde.

Research has shown that whirlwind-storms (hurricanes, or cyclones), originate at certain places, and pursue certain directions; for instance,—

(*a*) **West India hurricanes** (*Aracan* or *Huiran-vucan* of the coast of Mexico, *Vuthan* of Patagonia) commence on the inner edge of the N.E. trade-wind, and even within the trade-wind itself, especially in the latter part of summer and in autumn; and their whirling motion is caused originally by the S.E. trade encountering the N.E. trade, or by portions of the upper trade-wind descending from above. They progress from S.E. to N.W. in the torrid zone, then recurving at right angles at the outer edge of the trade-wind, they move from S.W. to N.E.; during the progression the whirlwind, revolving in a direction opposite to that in which the hands of a watch move, expands very considerably. In the region of the S.E. trade-wind of the Atlantic, whirlwind-storms occur with less frequency.

(*b*) **Typhoons** in the northern Indian Ocean and China Sea occur most frequently in autumn, but are also violent at the commencement of the S.W. monsoon. The direction in which they advance is rather more from E. to W. than from N.E. to S.W., especially on the south coast of China. In the southern half of the Indian Ocean they are likewise very violent, progressing there from N.E. to S.W., and recurving at right angles at the outer edge of the trade-wind, whence they advance from N.W. to S.E. The rotation of the air in the whirlwind-storms which occur in the northern hemisphere is in the opposite direction to that in which the hands of a watch move; and in the direction with watch-hands in the southern hemisphere. The causes which produce these effects lie in the juxtaposition of the regions of the monsoons and trade-winds, as well as in the displacement of one monsoon by the other.

Under certain local conditions, a whirlwind-storm may be so modified as to assume at particular spots the form of a steady wind; although, when its course is observed over a considerable distance, it shows itself to be a real whirlwind. This is the case, for instance, according to REDFIELD, with the *Northers* of the Gulf of Mexico, which, especially from September to March, at Vera Cruz, reach their greatest height four hours after they commence, and then blow for 48 hours with undiminished fury. REDFIELD explains this long duration of the storm from one direction, by the whirlwind, when advancing from the eastward, being arrested by the high land, and as a consequence flattened, so that its circular form is partially changed into a rectilinear one. The N.E. and N.N.E. storms of the Pacific Ocean, on the coasts of Nicaragua and Guatemala, known by the names *Papagallo* and *Tehuantepec*, are, according to REDFIELD, the fine-weather side of a whirlwind-storm; while the S.W. gales in August and September, which are called *Tapayaguas*, represent the other side.

It may not be wholly irrelevant to give, in this place, DOVE'S views as regard the behaviour and movements of meteorological instruments in connection with the "Law of Gyration:"—Calculating the mean of all the readings of the barometer, thermometer, and hygrometer, observed during each change of the wind, taken individually, after the elimination of the periodical changes,—that is, if we determine the mean distribution of pressure, temperature, and moisture round the compass, or, in other words, construct a *barometrical, thermal, and atmospherical wind-rose*,—it will be found that *this wind-rose has two poles of pressure and heat:*—that, in fact, there are two points, nearly opposite to each other, at one of which it is coldest, and the barometer highest; and at the other it is hottest, and the barometer lowest. From the maximum of pressure to its minimum, as well as from the maximum of heat to its minimum, the barometrical and thermal mean corresponding to different winds decreases uninterruptedly. The former point is situated nearly at N.E., and the other nearly at S W. Proceeding from S.W., through West, to N.E. the mean height of the thermometer decreases, whilst the mean height of the barometer increases; but from N.E., through East, to S.W. the mean height of the thermometer increases, whilst the mean height of the barometer decreases. What is perceptible in the mean height of the thermometer and barometer due to the winds must also appear in the mean movements of those instruments at the time of the transition of one wind into another, and this just as well on the hypothesis of a varying, as on that of a uniform, rotatory velocity. Since, however, the elasticity of aqueous vapour, so far as regards its distribution around the compass, is in close connection with the thermal wind-rose, but the pressure of dry air is closely connected with the barometric one, it follows that the changes in the pressure of dry air and of the barometer are precisely in an inverse ratio to the changes in the temperature of the air and the elasticity of the vapour suspended in it. Assuming then, as a necessary consequence of these theoretical considerations, that the N.W. point is the equivalent in the southern hemisphere of the S.W. point in the northern, and the S.E. point in the former corresponds to the N.E. point in the latter; we have the following—

MEAN MOVEMENTS OF METEOROLOGICAL INSTRUMENTS:

In the Northern Hemisphere:	*In the Southern Hemisphere:*
1. The Barometer falls with East, S.E., and South winds; changes from falling into rising with a S.W. wind; rises with West, N.W., and North winds; and changes from rising into falling with a N.E. wind.	1. The Barometer falls with East, N.E., and North winds; changes from falling into rising with a N.W. wind; rises with West, S.W., and South winds; and changes from rising into falling with a S.E. wind.
2. The Thermometer rises with East, S.E., and South winds; changes from rising into falling with a S.W. wind; falls with West, N.W., and North winds; and changes from falling into rising with a N.E. wind.	2. The Thermometer rises with East, N.E., and North winds; changes from rising into falling with a N.W. wind; falls with West, S.W., and South winds; and changes from falling into rising with a S.E. wind.
3. The Elasticity of Aqueous Vapour increases with East, S.E., and South winds; its increase changes into decrease with a S.W. wind; it decreases with West, N.W., and North winds; and its decrease changes into increase with a N.E. wind.	3. The Elasticity of Aqueous Vapour increases with East, N.E., and North winds; its increase changes into decrease with a N.W. wind; it decreases with West, S.W., and South winds; and its decrease changes into increase with a S.E. wind.

4. The Pressure of Dry Air decreases with East, S.E., and South winds; its decrease changes into increase with a S.W. wind; it increases with West, N.W., and North winds; and its increase changes into decrease with a N.E. wind.

4. The Pressure of Dry Air decreases with East, N.E., and North winds; its decrease changes into increase with a N.W. wind: it increases with West, S.W., and South winds; and its increase changes into decrease with a S.E. wind.

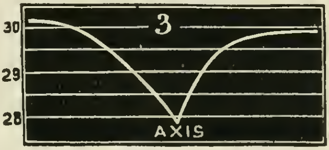
Thus, there is this in common between the two hemispheres,—the movements of meteorological instruments are the *same* with *East* winds in the NORTHERN HEMISPHERE as they are with *East* winds in the SOUTHERN; and the same is the case with *West* winds. The *difference* between the two hemispheres is only quantitative with N.W., N.E., S.W., and S.E. winds; and on the other hand it is qualitative with North and South winds; *i.e.* the mean changes of meteorological instruments are greatest in the Northern Hemisphere with N.W. and S.E. winds, and least (owing to the compensation of the opposite movements) with N.E. and S.W. winds; in the Southern Hemisphere (owing to the compensation of opposite movements) they are least with N.W. and S.E. winds, and, on the contrary, they are greatest with N.E. and S.W. winds. The changes with North winds in the Northern Hemisphere are, however, different from the changes that occur with North winds in the Southern Hemisphere: under like climatic conditions they are, however, according to their amount, the same in both hemispheres,—if, for instance, there be a rise in an instrument with a North wind in the Northern Hemisphere, it will sink with a North wind in the Southern, and *vice versa.* The same occurs with South winds.

In conclusion, the character of approaching weather as indicated by meteorological instruments, and the rules appertaining thereto, will be most simple in the zone of the trade-winds, because, in that region, the rotation of the earth (as shown by the simple circumstance of a constant direction in the initial and terminal points of the air-current) does not produce a regular shifting of the wind-vane, but its constant deflection, that is, a steady wind—which is the Trade; and the storms have only one form—that of the whirlwind. In the region of the monsoons they will be somewhat more complicated, because *there* the annual alternation of two air-currents produces one annual shifting of the vane, being periodical winds; and the storms, the form of which is likewise whirling, have, however, a less constant direction, and in fact must deviate in a certain degree from the prevalent one in order to produce a whirlwind. Lastly, they must be most complicated in the temperate zone, where the law of rotation is most completely developed, but storms occur in all forms hitherto known. The temperate zone has, however, this advantage over the torrid zone, that whirlwinds produce but modified effects as compared with the fearful violence of similar storms in the tropics, where they are so destructive.—DOVE.

Barometer.—Of all meteorological instruments the barometer is the most valuable to the seaman, even though its mean height for the geographical position is unknown to him.

Beyond the tropics, and in the higher latitudes, the oscillations of the barometer are incessant and irregular, ranging (rising and falling) through a space of 1½ to 2 inches, or even 3 inches on extraordinary occasions; and thus its indications fail at times to convey the same definite information that they do between the tropics, unless interpreted by the aid of the thermometer and hygrometer, in conjunction with various atmospheric and oceanic *appearances.*

Between the tropics the oscillations of the barometer are also incessant, but they are regular. The periodical range due to the season does not exceed a few tenths; but the most marked of the periodical oscillations is that which occurs *daily,* and this is so regular that Humboldt asserted that the hour of the day might be known within fifteen to seventeen minutes (on the average) by the height of the mercury. It shows every day *two maxima* and *two minima,* as follows, according to the locality; at some time between 9 and 11 a.m. the mercury begins to fall, and continues to do so until between 3 to 5 p.m., when it reaches the lowest point of depression; it then rises until between 9 to 11 p.m., when it reaches the highest point of elevation; after that it re-commences to fall, falling until between 3 to 5 a.m., from which time it again rises until between 9 to 11 a.m. The amount of range, again according to locality, varies from ·06 to ·12 of an inch. A daily oscillation is not confined to the tropics; it is equally existent in the higher latitudes, where however it is much smaller than in the vicinity of the equator, but is considerably masked by the frequent fluctuations to which the atmosphere is at all times subjected. The daily oscillation within the tropics is also very generally masked to a ship sailing from north to south, or from south to north, owing to her continual change of place, so that the barometer may appear to be tolerably steady: hence in equatorial and tropical regions any deviation from the usual mean—such as rising when it ought to fall, or falling when it ought to rise, or a change during a few hours of two or three-tenths of an inch, is a cautionary warning that the usual and regular state of the tropical atmosphere is disturbed, and that a hurricane has already commenced at a distance from the ship, in which case the barometer will continue to fall at a rate depending on the distance at which the ship is situated from the central calm as the hurricane passes in her direction. On the outer limits of the storm the barometer may be at its normal height, or even a little above it, say 30 or 30·1 inches; it falls more and more rapidly as the centre of the storm approaches, while within the calm area it has been found as low as between 27 and 28 inches, so that the barometric curve for the entire storm-field would present something of the form of Fig. 3.



Prognostications of unfavourable weather, and especially of an approaching hurricane, vary considerably, but between the tropics the barometer is an unerring monitor, and a rapid fall, after a few hours irregular oscillation, even when atmospheric and oceanic *appearances* are absent, is conclusive, and involves important consequences.

So far, then, the first stage in the history of the law of storms was the general recognition that hurricanes or cyclones are progressive whirlwinds, revolving around a calm centre, and that, whatever other prognostications might herald their approach and mark their continuance, the barometer is the most valuable monitor.

But these views did not pass wholly unchallenged. REDFIELD, when discussing the facts and observations he had accumulated, must necessarily theorise on the cause of hurricanes ; and in this he was unfortunate. He had two opponents in America, who, though they did not entertain precisely similar opinions on the subject, were yet, in the main, advocates of an "in-blowing theory" as opposed to the "circular theory" of storms—maintaining at the same time the progressive motion ; these opponents were Dr. ROBERT HARE and JAMES ESPY ; the former had written on gales and storms as early as 1822, and continued to oppose REDFIELD's views, and make occasional strictures on those of ESPY, until 1854 ; ESPY, as a writer on storms, dates from 1836 to 1857, and his chief works are the *Philosophy of Storms* and *Reports on Meteorology to the Surgeon-General of the United States Army.*

It cannot be denied that ESPY's views on, and theory of, storms, hurricanes, and tornadoes were favourably received by a large body of supporters. He had noticed the extraordinary fall of the barometer which accompanies these phenomena ; then, collecting facts and observations, as well as following the traces impressed on the ground in the track of hurricanes, he concluded that in those storms the air rushes directly from the exterior towards a central space ; so that, if the wind from one side blows east, it blows from the west on the other side, while the centre shifts its place. He recognised, as a cause of this "inblowing," an ascending column of air, the temperature of which does not vary, because the precipitation of its moisture restores to it the temperature it loses by expansion : this ascending column gives rise to a wind on the surface of the earth ; and above, to the formation of a *cumulus* which is immediately resolved into hail or rain. ESPY's theory explained in full is as follows :—

"When the air in any locality acquires a higher temperature or a higher dew-point than that of the surrounding regions, it is specifically lighter, and will ascend. In ascending, it comes under less pressure and expands ; in expanding from diminished pressure, it grows colder about $1\frac{1}{4}°$ Fahr. for every hundred yards of ascent. In cooling as low as the dew-point (which it will do when it rises as many hundred yards as the dew-point at the time is below the temperature of the air in degrees of Fahrenheit) it will begin to condense its vapour into water, or cloud. In condensing its vapour, it will evolve latent caloric; this evolution of latent caloric will prevent the air from cooling so fast in its farther ascent as it did in ascending below the base of the cloud now forming: the current of air, however, will continue to ascend and grow colder about half as much as it would do if it had no vapour in it to condense; and when it has risen high enough to have condensed by the cold of expansion from diminished pressure one-hundredth of its weight of vapour, it will be about 48° less cold than it would have been if it had had no vapour to condense, nor latent caloric to give out—that is, it will be about 48° warmer than the surrounding air at the same height; it will therefore (without making any allowance for the higher dew-point of the ascending current) be about one-tenth lighter than the surrounding colder air, and of course it will continue to ascend to the top of the atmosphere, spreading out in all directions above as it ascends, overlapping the air in all the surrounding regions in the vicinity of the storm, and fall still more under the storm-cloud by the outspreading of air above—thus leaving less ponderable matter near the centre of the up-moving column to press on the barometer below.

"The barometer thus standing below the mean under the cloud in the central region, and above the mean on the outside of the cloud, the air will blow on all sides from without inward under the cloud. The air, on coming under the cloud, being subjected to less pressure, will ascend and carry up the vapour it contains with it, and as it ascends will become colder by expansion from constantly diminished pressure, and will begin to condense its vapour into the cloud at the height indicated before, and thus the process of cloud-forming will go on.

"Now, it is known that the upper current of air in the United States moves constantly, from a known cause, towards the eastward—probably a little to the south of east; and as the upward-moving column containing the cloud is chiefly in this upper current of air, it follows that the storm-cloud must move in the same direction: and over whatever region the storm-cloud appears, to that region will the wind blow below; thus the wind must set in with a storm from some eastern direction, and as the storm-cloud passes, the wind must change to some western direction, and blow from that quarter till the end of the storm."

Thus Espy's theory is not wholly dissimilar from that of Brande, who wrote on the great European storm of 1782. It may be mentioned that Prof. Bache, the late superintendent of the United States Coast Survey was also a supporter of Espy's "in-blowing" theory.

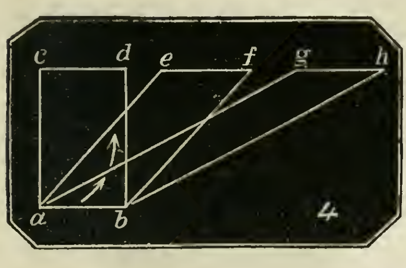
Now Redfield had been unfortunate in his first supposition that "the leading storms of the northern and western Atlantic, and of the American coast, originate in detached and gyratory portions of the *northern* margin of the Trade winds, occasioned by the oblique obstruction which is opposed by the islands to the direct progress of this part of the

Trade, or to these causes combined ;" and when his "circular" theory was threatened by an opponent's "in-blowing" one, he made more mistakes and many gratuitous assertions,—among the most remarkable may be mentioned that by which he explains the rotation of storms in a particular direction, on the assumption that the winds blow in horizontal circuits round the great oceanic basins, and his repudiation of the generally acknowledged theory of the Trade-winds, mainly, as it would appear, because that theory was "founded on the alleged effects of calorific rarefaction in the equatorial region :" from his stand-point there was no ascending current of air at the equatorial regions *overflowing* and passing off towards the temperate and polar regions, for rarefied air could not ascend except by means of "vorticular action," and this seemed his best argument against the "in-blowing or centripetal theory" of ESPY and HARE.

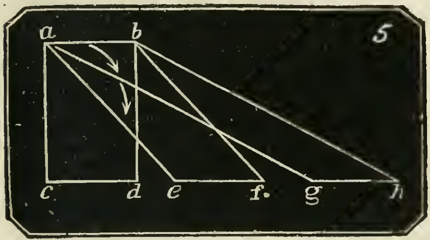
It may here be observed that HARE, REID and PIDDINGTON—but especially HARE and PIDDINGTON—ascribed the origin of hurricanes to an electrical or electro-magnetic disturbance of the atmosphere ; this is not singular, when we remember that not many years back every obscure natural phenomenon, especially in meteorology, was forthwith solved by referring it to an electrical cause : it is scarcely necessary to say that such origin for those storms is now regarded as untenable ; but there is no doubt that in most hurricanes electricity is developed to an enormous extent. PIDDINGTON also suggested that cyclones were originally formed above the earth, and that they descended, now horizontally (as horizontal discs), and now inclined at an angle, and that they both dilated and contracted in their progress.

DOVE's views have already been given in full (p. 17—24); he arrived at conclusions widely differing from those of ESPY, and strongly supported the "circular or rotary theory" as enunciated by REDFIELD, and developed by REID, PIDDINGTON and THOM. He admits of no centripetal theory, —no incurving of the winds, but, on the contrary, maintains that they blow at the circumference in a direction perpendicular to the radii of the circle, while their progressive motion may be curvilinear, as in the West Indian and Mauritius hurricanes, or rectilinear, as in some of the Indian and China cyclones. In explaining the cause of their combined rotatory and progressive motion, he takes the West Indian hurricane as typical of all others, and proceeds to show how it originates at the inner boundary of the N.E. trade-wind owing to the intrusion of the upper counter-current of the Trade into the lower current, or even through a part of the S.E. trade traversing the equator, entering the northern hemisphere, and producing similar results ; as for example,—

Take the line *a b* (Fig. 4) to represent, for the Northern hemisphere, a series of molecules of air parallel with the equator, and which are set in motion towards the North, in the direction *a c ;* if the space *d b h* were empty or void, these molecules would tend towards *g h*, because their progression takes place from larger parallel circles towards those which are smaller. But if the space *d b h* be filled with air at rest, the molecules at *b* must encounter, on their way towards *d*, others having less velocity of rotation, the effect of which will be to diminish their velocity towards the East, and consequently the air at *b*, instead of moving towards *h*, would tend towards *f*. The molecules between *a* and *b* are also affected—but differently and to a smaller extent—moving more towards *g*. It follows that if *a b* be a mass of air pressing forward from south to north, the direction of the storm-wind will be much more from south on its east than on its west side, where it will be more westerly, and thus a tendency to whirl (or rotate) originates in the direction S., E., N., W. This tendency to whirl would not exist if there were no opposing mass in the space *d b h;* but, on the other hand, it will augment in proportion to the opposition of the two forces, and the westerly deflection of the storm is checked; and the storm itself will rotate the more violently, the more it retains the original direction of its course.



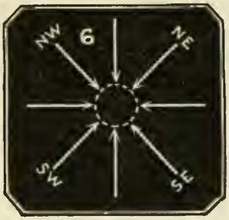
In the zone of the Trade-winds the space *d b h* is filled with air moving from N.E. towards S.W.: and it is there that the opposition will be greatest. The air at *b* may be checked to such an extent that it will preserve, unaltered, its direction towards *d*, while that at *a* has a tendency in the direction of *g*. The storm will therefore rotate with greatest force in the torrid zone, but at the same time preserve its dimensions unchanged. As soon, however, as it enters the temperate zone, it comes to a region where the space *d b h* is already full of air moving from S.W. to N.E. The resistance which the air at *b* had previously experienced is now suddenly diminished, or wholly ceases, and instead of taking the direction *b d* it turns sharply in that of *b h*. The storm thus bending round suddenly at right angles to its previous direction, rapidly expands its dimension, since the differences in motion between the points *a* and *b* no longer exist.

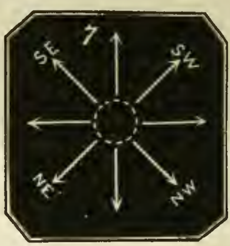


The hurricanes of the Southern hemisphere originate from the same cause, but the rotation takes place in the opposite way (Fig. 5), while the change of direction on the borders of the tropic is analogous to that which takes place in the Northern hemisphere.

It may be remarked, in passing, that Dove is a strong supporter of the ascending current in the region of the equatorial *calms*.

Before proceeding further it may be as well to compare the three systems—the centripetal or "in-blowing," the centrifugal or "out-blowing," and the "circular or rotatory,"—to note where there is similarity, and where dissimilarity, whether they are stationary or have progression in any particular direction.

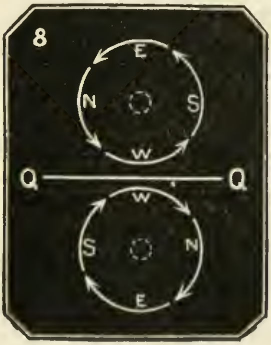




The perfectly *centripetal* or "in-blowing" system is seen in Fig. 6, where the winds blow in all directions *towards the centre*, in such manner that they are *northerly* on the *north* side, *easterly* on the *east* side, *southerly* on the *south* side, and *westerly* on the *west* side. This would be the same for both hemispheres. At the centre there is a calm area. There is no rotatory motion of the winds, though there may be progression in a definite direction, which would give an *apparent* veering of the wind either with or against the sun's motion.

The perfectly *centrifugal* or "out-blowing" system is seen in Fig. 7: in it the winds blow in all directions *from the centre*, and consequently directly opposite to those of the "in-blowing" system: thus, they are *southerly* on the *north* side, *westerly* on the *east* side, *northerly* on the *south* side, and *easterly* on the *west* side, for both hemispheres—with a central calm area. In this case, also, there is no rotatory motion, but should there be progression in a definite direction, there must also be an *apparent* veering of the wind with or against the sun's motion.

In the circular and rotatory system the wind, according to the popular idea, rotates around a central calm area, in a direction from *right to left* in the *northern* hemisphere, but from *left to right* in the *southern* hemisphere—or, to use a familiar illustration, contrary to the motion of the hands of a watch in the northern, but coincident therewith in the southern, hemisphere, and which is consequently *contrary to the apparent course of the sun in each hemisphere* (*see* Fig. 8). Hence it follows that, in the *northern* hemisphere the winds must be *easterly* in the *northern* quadrant, *southerly* in the *eastern* quadrant, *westerly* in the *southern* quadrant, and *northerly* in the *western* quadrant; while, for similar quadrants in the *southern* hemisphere, the direction of the winds must (since the rotation is reversed)



be the reverse of those just given—*i.e.*, *westerly* in the *northern* quadrant, *northerly* in the *eastern* quadrant, *easterly* in the *southern* quadrant, and *southerly* in the *western* quadrant. And further, in each hemisphere, the winds must be *westerly* on the equatorial side of the storm.

One of the earliest axioms supposed to be established in connection with the rotatory theory of storms was, that, in each hemisphere, the *centre* of the storm always bore *eight points from the wind, reckoned with the sun;* such that in the N. hemisphere, when facing the wind, the centre would be square to the right; in the S. hemisphere, square to the left.

So also, as a consequence of the circular motion of the wind round a centre, combined with a bodily progressive movement, other two important axioms were thought to be established, as if appertaining exclusively to rotatory storms—viz., that on the passage of such a storm over a place or ship—

In the *N. hemisphere* the veering of the wind in the *right hand* semicircle must coincide *with* the apparent course of the *sun*, while in the *left hand* semicircle it would be *against* the apparent course of the *sun.*[*]

In the *S. hemisphere* the veering of the wind in the *right hand* semicircle must be contrary to (*against*) the apparent course of the *sun*, while in the *left hand* semicircle it would coincide *with* the apparent course of the *sun.*[*]

Such, in brief, is the "Law of Storms" on the rotatory theory.

It has already been shown (p. 18) that, for the N. hemisphere, veering in the direction E., S., W., N., E. is *with the sun;* and W., S., E., N., W. is *against the sun;*—and,

For the S. hemisphere, veering through E., N., W., S., E. is *with the sun;* and W., N., E., S., W. is *against the sun.*

A glance at Figs. 6, 7 and 8, in conjunction with the more explicit statements in the following table, will show that, for the three systems of winds—the centripetal, centrifugal and circular—though, for any given side of the area within which the wind is blowing, the *direction* of the wind is totally *different*,—the *veering*, as *with* or *against* the *sun*, is precisely *similar* in all, and not confined to the circular or rotatory storm.

N. HEMISPHERE.	*Centripetal.*	*Centrifugal.*	*Circular.*	
Progres. motion to N.W.	Wind veers	Wind veers	Wind veers	
On right hand[*]	N.-N.E.-E.	S.-S.W.-W.	E.-S.E.-S.	with sun
On left hand	W.-S.W.-S.	E.-N.E.-N.	N.-N.W.-W.	against sun.
Change of wind at centre	N.W. to S.E.	S.E. to N.W.	N.E. to S.W.	
Progres. motion to N.E.	Wind veers	Wind veers	Wind veers	
On right hand	E.-S.E.-S.	W.-N.W.-N.	S.-S.W.-W.	with sun
On left hand	N.-N.W.-W.	S.-S.E.-E.	E.-N.E.-N.	against sun.
Change of wind at centre	N.E. to S.W.	S.W. to N.E.	S.E. to N.W.	

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[*] Right and left in this case have reference to the track, as if *looking towards the direction in which the storm is bodily progressing.*

S. HEMISPHERE.	*Centripetal.*	*Centrifugal.*	*Circular.*	
Progres. motion to S.W.	Wind veers	Wind veers	Wind veers	
On right hand	W.-N.W.-N.	E.-S.E.-S.	S.-S.W.-W.	against sun
On left hand	S.-S.E.-E.	N.-N.W.-W.	E.-N.E.-N.	with sun.
Change of wind at centre	S.W. to N.E.	N.E. to S.W.	S.E. to N.W.	
Progres. motion to S.E.	Wind veers	Wind veers	Wind veers	
On right hand	S.-S.W.-W.	N.-N.E.-E.	E.-S.E.-S.	against sun
On left hand	E.-N.E.-N.	W.-S.W.-S.	N.-N.W.-W.	with sun.
Change of wind at centre	S.E. to N.W.	N.W. to S.E.	N.E. to S.W.	

The most marked characteristic in the three systems is the change in the direction of the wind as the centre passes over a place; in each it is from a given point to another directly opposite; but on the circular theory the change must always occur through two opposite directions, each of which is perpendicular to the movement of translation,—for example, in the N. hemisphere, with the storm moving to N.W.-ward, the change at the centre will be from N.E. to S.W.

All these points of similarity and difference must be borne in mind in connection with the new views that are held by eminent meteorologists in respect to hurricanes.

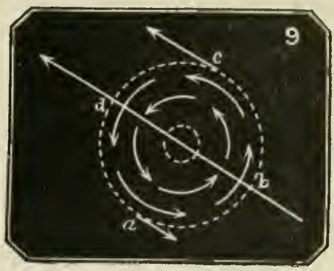
The laws and rules briefly indicated on p. 32—33, and respecting which it has been said that "nothing can be more definite and unambiguous," have also been accepted in their hard and fast condition by all French authors; and in a work recently published the following illustration of the effect of the combined motion of translation and rotation is to be found:—

Take the case of a storm, in the northern hemisphere, moving towards the N.W. at the rate of 8 miles an hour, and in which the rotatory velocity of the winds is 80 miles: if tangents be drawn to the circle such that they represent the velocity of rotation (80 miles) as one component, and straight lines of one-tenth that length (8 miles) be drawn parallel with the track of the storm, as the other component; on completing the parallelograms of which these are the sides, the diagonals of the parallelograms will give the resultant winds—both as regards direction and velocity. On such a projection the winds at the different parts of the storm will be, in respect to direction,—

At S.W. part, wind N.W.
S. ,, ,, W.½S. instead of West.
S.E. ,, ;, S.W.½S. instead of S.W.
E. ,, ,, S.½E. instead of South.
N.E. ,, ,, S.E.
N. ,, ,, E.½S. instead of East.
N.W. ,, ,, N.E.½E. instead of N.E.
W. ,, ,, N.½E. instead of North.

Now, it is not a little curious that, on the supposition of the winds having the direction just given, they would be slightly centrifugal on the advancing semicircle of the storm, but slightly centripetal on the receding half.

Again, following out the author's illustration, the sum of the two components (80+ 8), viz., 88 miles, would be the velocity of the wind at the N.E. part of the storm (*c* in fig. 9); and the difference of the components (80−8), *i.e.* 72 miles, would be the velocity of the wind at its S.W. part (*a* in fig 9): and thus, from the *minimum* at *a* the velocity would increase alike on the advancing and receding semicircles, *i.e.* in the directions *a d c* and *a b c*, until it attained its *maximum* at *c*. But, it is not difficult to see that whatever accuracy there may be in the first part of the illustration, the latter part cannot be correct, for the reason that the *sum* of the resultants in the right hand semicircle would be in excess of those in the left hand semicircle, and the storm could not advance far before the former half had shot ahead and left the other half behind,—though indeed a succession of rotatory storms might be formed in this way.



It may be well, at this point, to inquire whether the founders of the rotatory theory of storms laid down hard and fast laws and rules for the guidance of mariners, such as their followers have done?—There is no doubt that they did,—but almost invariably with many subsequent qualifications, and much explanation as to apparent anomalies; so that, far from everything in connection with the theory and practice being "definite and unambiguous," the reverse is the case. It may indeed be said that they gave but a very qualified adhesion to much that has been enunciated for the last 30 or 40 years as the true principle of the law of storms.

Redfield, writing in the *American Journal of Science*, in 1846, says;—"When, in 1830, I first attempted to establish by direct evidence the rotative character of gales or tempests, I had only to encounter the then prevailing idea of a general rectilinear movement in these winds. Hence I have deemed it sufficient to describe the rotation in general terms, not doubting that on different sides of a rotatory storm, as in common rains or sluggish storms, might be found any course of wind, from the rotative to the rectilinear, together with varying conditions as regards clouds and rain.

"But I have never been able to conceive that the wind in violent storms moves only in circles. On the contrary, a vortical movement, approaching to that which may be seen in all lesser vortices, aerial or aqueous, appears to be an essential element of their violent and long continued action, of their increased energy towards the centre or axis, and of the accompanying rain. In conformity with this view the storm figure on my chart of the storm of 1830 was directed to be engraved in spiral or involute lines, but this point was yielded for the convenience of the engraver. * * * * *

"The common idea of rotation in circles, however, is sufficiently correct for practical purposes, and for the construction of diagrams, whether for the use of mariners, or for determining between a rotative and general rectilinear wind, on one hand, or the lately alleged centripetal winds on the other. The degree of vorticular inclination in violent storms must be subject, locally, to great variations; but it is not probable that on an average of the different sides, it ever comes near to forty-five degrees from the tangent of a circle, and that such average inclination ever exceeds two points of the compass, may well be doubted."

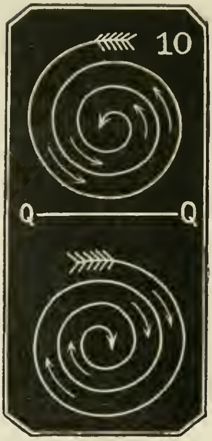
Ried, equally with Redfield, saw the weak points of a purely circular theory, and hence, in his *Progress of the Development of the Law of Storms*, he writes:—

"On the approach of a revolving storm, the weather is sometimes calm, or the wind is unsteady, or *it may draw towards* the storm; and when this occurs it may be difficult to determine the exact point of the compass from whence the true whirlwind sets in. In like manner, it may not always be easy to determine the exact point at which a gale ends."

And reverting to the subject, he says,—

"But a circle will only correctly represent a whirlwind when stationary. In the progressive whirlwind the figure would become cycloidal, and the degree of curvature would depend upon the rate of progress of the storm. While attempting to lay down a storm's track, a wrong judgment may be formed, if data be rejected on account of its not conforming to a figure exactly circular." Then, using the track of the *Charles Heddle* reversed, as for the *northern* hemisphere, he says "at the point *a* the wind would be north; at the point *b* (due east of the point *a*) it would be S.W.: circles, nevertheless, have been found the most convenient figures in endeavouring to explain the nature of storms."

Piddington devotes eight pages of his *Horn-Book* to discussing the "probability of the incurving of the winds in a cyclone," and the "flattening in of the circle of a cyclone"—quoting, at the same time, with approbation, the extract from Redfield, given above. It appears to him "not improbable that, while at some point in the whole zone of a cyclone the wind may be blowing in a true circle, it may on the inner or central side of that part be a series of *in*curving spirals, and that on the outer part there may be a centrifugal (*i.e.*, a curving *off from* the centre) tendency." He also expresses the view, as a probability or possibility, "that when cyclones are increasing in diameter or dilating, the spiral is a diverging one, or that the arrows (of the wind) curve outwardly, and when it contracts the spiral is a *con*verging or incurving one:" and in another place he says, "it would seem also that this incurving takes place sometimes at a distance from the centre." Piddington is generally full of instances, and according to his usual practice, adduces examples illustrating the remarks quoted above; he particularises ships' logs which indicated an alternation or shifting of the wind through four, five and more points, and infers that one vessel "by the alternating of the winds must have drifted over a succession of curves." It is also by "an excessive incurving of the winds towards the centre" that he finds "an explanation of how some ships (when disabled) may be blown and drifted round and round, without drifting out of the fatal centre:" and he concludes his observations as follows,—"perhaps a further proof, or rather an indication of this incurving may be found in the remarkable instances of ships being surrounded or having their decks covered during the passage of the calm centre of cyclones, in the neighbourhood of the land, with land and aquatic birds, butterflies, horse-flies, &c.; now within a cyclone these animals must be incapable of doing more than keeping themselves in the air; . . . . . . they must therefore, we may suppose, be gradually carried inwards by the incurving tendency of the winds, and at the centre are kept there because they cannot fly out of it; . . . . if the wind blew in true circles they would be scattered all over the body of the cyclone."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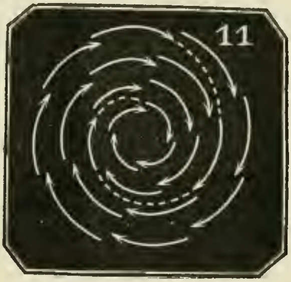
It has been seen that Redfield and Piddington agree in this—that the incurving of the winds in a hurricane may amount to fully two points, if not more. No diagrams have been given to show the character of this incurving, as they understood it—so that some have taken it to be of a spiral kind, as represented in Fig. 10; while others have supposed it to approximate to the form of Fig. 11—which is really an incurved spiral (*see* dotted lines)—but circular as the centre is approached. There is no doubt that Reid, equally with Redfield and Piddington, wavered in opinion as to the precise form of of a cyclone; but nevertheless all three gave *very positive* rules, especially as to the direction of the winds on the different sides of a hurricane,—and as to the bearing of the centre, taking the wind as a guide: it is true that cautionary paragraphs constantly occur in their writings, such as very considerably modify the positive character of their previous rules; but subsequent authors, and the devotees of the circular theory, have persistently lost sight of the cautions, and only given, in a very dogmatic manner, the "definite and unambiguous" rules,—forgetful that the backing and filling is of their very essence: for, as a shipmaster has written "if the centre *always* bore eight points from the direction of the wind; if the wind *gradually* increased in force as we near the centre; if the wind veered *gradually* in all parts of the storm; and if the centre were the *only* dangerous part of it, then the avoiding of a hurricane would be very simple."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To sum up, though REDFIELD, REID and PIDDINGTON at first conjectured a purely circular and rotatory action for the winds within the area of the storm-field, they came at last to modify this view, as a deduction from the observations submitted to them; and they conceded this much—that at least in some hurricanes, if not in all, there must be a *slight incurvature* of the winds: but they had no distinct perception to what extent this deviation existed, and, consequently, as the practical rules deduced from the law of storms were already in the hands of those for whose benefit they were written, they were careful to note the anomalies while leaving the rules unmodified. Their followers elaborated the one and neglected the other.

THOM, as before observed, was also a supporter of the rotatory theory of hurricanes, and he has much to say on the varied aspects of these storms as they occur in the Southern Indian Ocean: but in respect of the manœuvring of ships when endeavouring to steer clear of, or when contending with, their fury, he merely *suggests* the course to be pursued, and his remarks are not to be taken as arbitrary rules, "for it is obvious that general rules cannot be made applicable to every case."

It is, however, worthy of note that THOM was one of the first to indicate that the hurricanes of the Southern Indian Ocean had their origin in the region of calms or "variables" between the N.W. monsoon and the S.E. trade. His observations are as follow:—

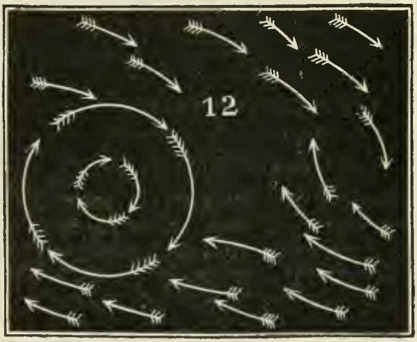
"We have two great winds blowing, in contrary directions, from one side to the other of the Indian Ocean, between the equator and the tropic, the one depending on fixed and permanent laws, and the other, periodically called into existence by agencies of a temporary duration, exerting an almost antagonist force to the former. As the solar action takes place in a gradual manner, the recession of the trade-wind, and establishment of the monsoon, follow in a corresponding degree: the sky is serene and clear, indicating an increasing temperature in the upper regions of the atmosphere, and a rising dew point. But, as soon as the sun begins to leave the tropic, and the heat to decline, the changes contingent on the subsidence of the monsoon take place in a sudden and unequal manner, and it would seem often give rise to those fearful conflicts of elementary forces which form the subject of our present inquiry.

"Between the two winds in question, about lat. 10° to 12° S., there is an intervening space of several degrees of variable and light winds, or calms, distinguished by an unsettled state of the atmosphere, exactly similar to that which occurs between the S.E. and N.E. trade-winds in the Atlantic. In approaching this tract, the S.E. trade deflects to South, and the westerly monsoon to N.N.W. or North. At the meeting of these currents of air, or rather in the neutral interval, sudden squalls, lulls, thunder-storms, and heavy rains, are usually experienced. This is to be expected from the very different conditions of the two winds, for they are not only diametrically opposite in their direction, but as dissimilar in reference to their respective temperature, humidity, and specific gravity, as it is well possible for two neighbouring masses of air to be.

* * *

"During the presence of the sun in the southern hemisphere, a constant struggle between the two opposite currents of atmosphere may naturally be expected to take place along the interval which separates them. Not only theory, but observation establishes this fact. On the borders of the two winds, ships meet unsettled weather, and variable winds,—at one moment are in a calm, and the next, perhaps, laid on their beam-ends by a squall. It is in this situation that thunder-storms and whirlwinds abound. To this tract we wish to direct attention, as being not only the locality where rotatory storms are first formed, but along which they move during the greater part of their course, till they acquire an intestine and specific action, involving the neighbouring currents of the atmosphere, which enable them to advance through the trade-wind to its opposite limits.

"Two currents of atmosphere in motion from opposite points, on approaching the neutral columns of air which intervene between them, cannot be supposed to lose their momentum, or to have their velocity suddenly arrested, or even materially diminished; on the contrary, we must suppose that their motion will be diverted into a new channel. From a knowledge of the forces which propel the currents towards one another, we are prepared to expect that the S.E. trade will have a constant tendency, in a greater or less degree, according to accidental circumstances, to deflect towards the equator, and blow across the line of "variables" into the region of the monsoon. This deviation will be favoured by any temporary diminution of the antagonist force of the opposite current. Suppose, for instance, a sudden elevation of temperature, and consequent vertical current at some part of the monsoon, a considerable barometrical depression must follow, and a rush of the surrounding atmosphere would take place towards the point of diminished pressure, but with greatest force from that side where the heavier and cool S.E. trade-wind was pressing onwards at the earth's surface. This last current, on entering the hotter locality of the monsoon, would quickly acquire its temperature and relative degree of moisture, and consequently its direction. A portion of the trade-wind, in undergoing this change, would curve from its natural course S.E. to South, till it mixed with the monsoon, and then become a S.W., West, and N.W. wind. (*see* Fig. 12.)



12

"Now, the new and periodical agencies which communicate a N.W. direction to the monsoon, evidently cause it to blow from the equator, so that at the point where it meets the trade-wind its course would be North, and from its greater degree of rarefaction would ascend and pass over it. But, in doing so, a portion of it must gradually mix with the colder S.E. wind, lose some of its heat, and partake of the character and assume the direction of the latter, in the course of which it would be found veering from N.W. to North and N.E.

"Thus, by the natural deflection of the two winds in opposite directions, a constant tendency would exist in the atmosphere interposing between them to assume a circular motion. The curve of the trade-wind from East by S.E., to S. and S.W., to unite with the monsoon, amounts at least to half a circle, while the inclination of the latter from the equator, or in a reverse direction to the former, and to an equal extent, would form the opposite half of a completely connected circle. * * *

"In every case where a circular storm is clearly determined, a branch of the S.E. trade is found to cross the line of "variables" and enter the monsoon, while the latter recrosses into the former, each gradually deflecting till it appears to be part of the other, and both revolve around a common centre (*see* Fig. 12). It has been shown that the disc of atmosphere in a state of rotation is progressive, and, at places over which the centre passes, its first approach is detected by the increasing violence of the S.E. trade, and its departure by a N.W. wind; so that throughout the whole progress of the storm the relative positions of the two winds are preserved. Even the peculiar characteristics of each, as already described, are easily recognised at that part of the circle to which they belong. There is another circumstance worthy of notice in reference to the mutual action of the two currents when involved in a circular motion, which is, that during the early stages the N.W. predominates over the S.E., but, as the hurricane moves towards the tropic, it is exactly the reverse. In lat. 20° and 22° S., the S.E. trade often prevails with tempestuous violence for several days before the vortex arrives; but when the N.W. or west part of the storm sets in, although it blows with equal severity for ten or twelve hours, it seldom continues much longer. * * *

"Whether the opinions which have been advanced regarding the formation of rotatory gales approach the truth, must in some measure depend on future observation; one point, however, seems to be satisfactorily ascertained, that they are generally developed in the interval between, what we may be allowed to call, their parent winds, and in intimate relation with both, in such a manner that each would convey additional impulse to the revolving mass at the opposite sides of the circle. In this manner a storm may be supposed to receive accessions of impetus at the exterior of the circle, by the conversion of the rectilinear force into a circular motion, and by enlarging the sphere of its action it would impinge more extensively on neighbouring winds, and receive a continuous support. Even if the contiguity of two winds is not required to form a rotatory motion in the atmosphere, it appears to be absolutely necessary for the continued existence of such an action. There seems to be no other cause adequate to explain the duration of hurricanes for fifteen or twenty days, while travelling along a distance of 3000 miles: and finding that they arise between regular but opposite currents, continue their progression in the same relative position, and only terminate or lose their specific action at that point where the two winds cease to be regular, or near the extra-tropical "variables," it is consonant to reason to trace a connexion of cause and effect between them."

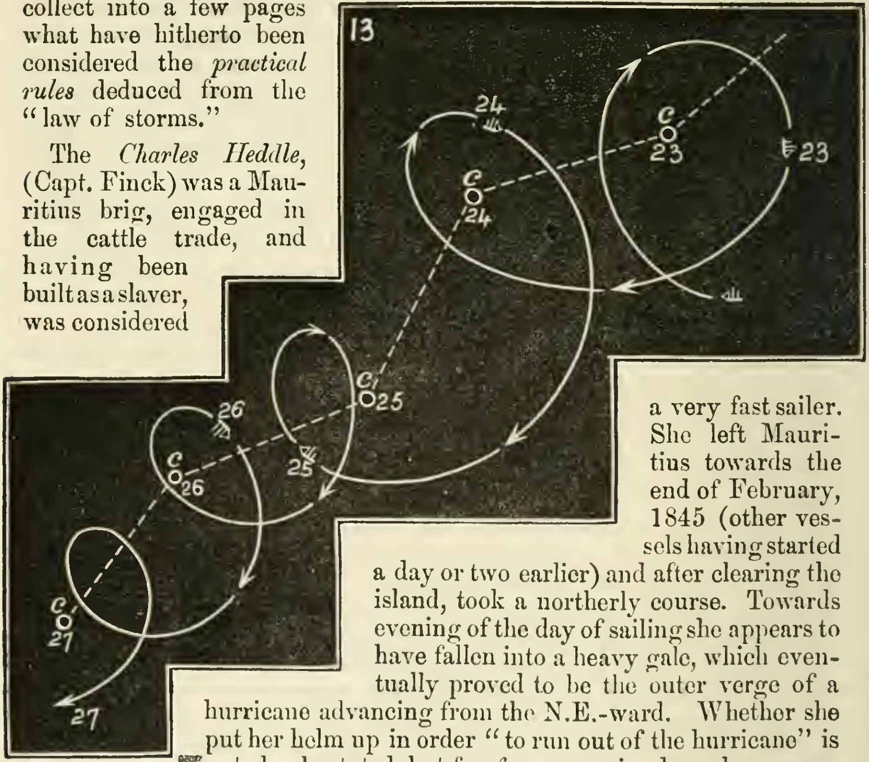
From THOM'S stand-point there is no hurricane until the winds shall have assumed a rotatory, or approximately rotatory, character; he, however, admits that even within the area of the storm-field the winds are often fitful and irregular, both as regards direction and force, and speaks of "alternate lulls and fierce spiral gusts in the vicinity of the vortex;" but his happy exposition of the origin of such storms—"from a constant struggle between two opposite currents" of air—clearly indicates that on the borders of the hurricane there must be a considerable space where the "parent winds," that "convey additional impulse to the revolving mass," are stormy and tempestuous to such a degree as to render it "difficult," as REID says, "to determine the exact point from whence the true whirlwind sets in;" and THOM'S diagram, a portion of which is given on page 39, is very suggestive on this point.

THOM'S explanation of the origin of the cyclones of the Southern Indian Ocean was written in 1845, but at that time it did not receive much attention. Some years afterwards, when the Mauritius Meteorological Society was in full activity, and the storms of that region had become a constant subject of discussion among its members, Mr. MELDRUM, the able secretary of the society, was enabled by fuller investigation to corroborate and develop the views and opinions enunciated by THOM in respection to the locality where cyclones are generated; and in 1861 he wrote,—

"The more the Hurricanes of the Southern Indian Ocean are studied, the more evident does it become, that they owe their origin and continued existence, for several days, to the vibrating and conflicting action of the equatorial Westerly monsoon and the S.E. trade-wind, when the sun has southern declination. Between these two systems of winds there is a belt of maximum heat, and consequently of atmospheric rarefaction, with light and variable winds; and towards this space of diminished pressure the monsoon and trade-wind flow from opposite directions, bringing with them the vapours which have been generated on either side. This belt of variables is inclined obliquely across the ocean, extending further south on its western side, towards the heated land; and it also has, within certain limits, a vibratory motion from north to south, and *vice versa*, along its whole extent,—the trade and monsoon reigning alternately in the same localities. The monsoon, however is the aggressor, being backed and pressed upon by a much greater extent of cold and heavy air than its opponent; and it is during its irruptions into the trade-wind region that hurricanes take place.

"It might be expected that as the line of demarcation between the two winds has a great extent in longitude, so several hurricanes (or cyclones) might be formed between them at the same time, but at considerable distances apart; and observation shows that this is the case. Several instances occurred in 1860, particularly in February. During the last ten days of that month, the equatorial borders of the trade, along its whole extent, were in a state of stormy gyration, and several distinct cyclones raged at the same time. The same thing has again occurred this year (1861)."

This appears to be the place for introducing the celebrated case of the brig *Charles Heddle* which gave such impetus to the *purely* circular theory of hurricanes; after which, and before proceeding to discuss the more recent views of meteorologists in respect to hurricanes, it will be most appropriate to collect into a few pages what have hitherto been considered the *practical rules* deduced from the "law of storms."



The *Charles Heddle*, (Capt. Finck) was a Mauritius brig, engaged in the cattle trade, and having been built as a slaver, was considered a very fast sailer. She left Mauritius towards the end of February, 1845 (other vessels having started a day or two earlier) and after clearing the island, took a northerly course. Towards evening of the day of sailing she appears to have fallen into a heavy gale, which eventually proved to be the outer verge of a hurricane advancing from the N.E.-ward. Whether she put her helm up in order "to run out of the hurricane" is not clearly stated, but for *five* successive days she was apparently scudding right before the wind, as shown by the following extract from her log-book, and from which Piddington deduced the remarkable track given in Fig 13. (*c* shows the storm's centre.)

Log of the Brig CHARLES HEDDLE, *of Mauritius, Captain* FINCK; (*kept in French*), *copied by Captain* ROYER, *Master Attendant at that Port, and translated by* HENRY PIDDINGTON. *Nautical Time.*

H.	K.	F.	Courses.	Winds.	Remarks.
P.M.					
1	5	4	N E b N	E S E	*Friday 21st to Saturday 22nd February*, 1845. Horizon very low (*tres rapproché*), thick weather all round. Heavy sea, smart breeze, under the large sails; pumped every two hours. Sea and wind gradually increasing, vessel labouring greatly, weather squally and threatening all round; the squalls very heavy. At 9.30 P.M. the mainyard went in two in the slings, clued up and furled main-topsail, unbent main-sail, and secured the pieces of the mainyard on the booms. In jib and mizen; scudding under the foresail, fore-topsail and fore-topmast staysail, to wait for daylight; heavy squalls and sea. Down main-topsail yard, and struck top-gallant-mast. Noon, in close-reef fore-topsail. The gale begins to make itself be felt; scudding under foresail, and fore-topsail.
2	5	4		Variable to S E	
3	5	4			
4	5	4			
5	6				
6	6				
7	7				
8	7	4			
9	7				
10	7				
11	6				
12	6				
A.M.					
1	6	4	North	S E	
2	6	4		S S E	
3	6	4			
4	6	4			
5	6				
6	6				
7	7				
8	8				
9	8				Latitude by Account ... ... 16° 42′ S.,
10	8				Longitude Account ... ... 57° 45′ E.
11	8				
12	8				
P.M.					
1	*13	...	W N W	E S E	*Saturday 22nd to Sunday 23rd February.* Very bad weather; frightful sea; blowing very hard with incessant rain; vessel taking in seas over the quarter while scudding under the foresail and close reefed fore-topsail. Pumped every hour; vessel labouring greatly from the seas which swept over us. At 2 P.M. perceiving that the head rope of the foresail had given way, sent two hands to cut away the earings, and let it come on deck; saved the sail. The fore-topmast staysail halyards having given way hoisted the sail by a tackle. Gale at its height, scudding right before the wind, as it continually veered round the compass; pumps attended to; vessel labouring excessively. It being impossible to clue up the fore-topsail without risking severe damage, we resolved to run our chance of what might happen. N.B. No position is given on this day.—H.P.
2	13	...	N W	S E	
3	12	...	N N W	S S E	
4	11	...	North	South	
5	11				
6	11				
7	12				
8	12	...	N N E		
9	12				
10	12	...	N E		
11	12				
12	12				
A.M.					
1	12				
2	12	...	E N E		
3	12	...	East		
4	12				
5	12				
6	12				
7	12	...	E S E		
8	12				
9	12				
10	12	...	S E		
11	12	...	S S E		
12	12	...	South	North	
			S W	N E	
				E N E	
				East	
				E S E†	

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* *About* is marked in the log.

† These last winds and courses are so marked in the log, I presume they mean to designate the changes between Noon and 1 A.M. on the next day, as a memorandum of a gradual veering. —H.P.

Log of the Brig Charles Heddle.—*continued.*

H.	K.	F.	Courses.	Winds.	Remarks.
P.M.					*Sunday 23rd to Monday 24th February.* Weather always the same with a frightful sea. Shipping from time to time very heavy seas; one filled the whole deck fore and aft with two feet of water; the larboard waist-board carried away; much water going down the hatchways and cabin scuttle, though all secured by tarpaulins. 4 P.M. fore-topsail blew away; scudding under bare poles; the new fore-topmast staysail giving way, saved it; two men at the helm, vessel labouring greatly; storm always at the same height; winds veering round the compass from hour to hour, and even in half an hour.[*] Brought all the crew aft into the cabin to be at hand, closed up the fore-scuttle. N.B. No position given on this day.—H. P.
1	12	...	S W	N E	
2	12	...	W S W	E N E	
3	12				
4	12				
5	12				
6	12	...	West	East	
7	12				
8	12				
9	12	...	W N W	E S E	
10	10	...	N W	S E	
11	10	...	N N W	S S E	
12	10				
A.M.					
1	10				
2	10				
3	11	...	North	South	
4	11				
5	11				
6	11	...	N N E	S S W	
7	11	...	N E	S W	
8	11	...	E N E	W S W	
9	11				
10	11				
11	11	...	East	West	
12	11				
P.M.					*Monday 24th to Tuesday 25th February.* The gale always at the same degree of strength, but the squalls a little heavier, pumps always in hand, vessel making water. All the cabins below wet, the provisions in the great cabin also wet, the vessel making water through every seam in the deck without exception; baled the water out of the cabin by buckets. Shipped several seas which went over all. At two in the morning the vessel broached-to, the water two feet deep on the deck; we remained in this dangerous position for about ten minutes, when she righted. We broached-to again several times from the speed of the vessel;[†] cleared the scuppers. At 10, shipped a sea in the fore rigging which carried away jib and flying jib-boom. Cut away the wreck to clear the bowspit. Latitude by a doubtful Observation ...16° 18′ S. Longitude Chronometer... ... ...53° 2′ 30″ E.
1	11	...	E S E	W N W	
2	12				
3	12				
4	12	....	S E	N W	
5	12				
6	11				
7	11				
8	11	...	S S E	N N W	
9	11	...	South	North	
10	11				
11	11				
12	11				
A.M.					
1	11	...	S S W	N N E	
2	11	...	S W	N E	
3	11	...	W S W	E N E	
4	11				
5	11				
6	11	...	West	East	
7	11	...	W N W	E S E	
8	11				
9	11	...	N W	S E	
10	11				
11	11	...	N N W	S S E	
12	11				

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[*] The expression is "*faisant le tour du compas d'heure en heure et meme une demi heure*," of which the literal translation would be, "going round the compass from hour to hour and even in half an hour." What is meant is evidently (by the log) that the wind was going round the compass and *changing* every hour or every half hour.—H.P.

[†] The words are "*par la vitesse du batiment.*" No doubt the difficulty of steering her is here implied.—H.P.

Log of the Brig Charles Heddle.—*continued.*

H.	K.	F.	Courses.	Winds.	Remarks.
P.M.					*Tuesday 25th to Wednesday 26th February.*
1	11	...	North	South	The gale always at the same strength without the least intermission, heavy sea and rain. The tiller ropes gave way ; changed them ; then the bolts also of the tiller having given way, drove in preventer ones. Pumped ship every hour. The trusses of the fore-yard gave way, replaced them ; scudding under bare poles. The sea frightful, vessel making much water through the deck. Crew worn out with fatigue. The sun appeared indistinctly at noon whereby we obtained an indifferent latitude and longitude.
2	11	...	N N E	S S W	
3	11				
4	10	...	N E	S W	
5	10	...	E N E	W S W	
6	10	...	East	West	
7	10	...	E S E	W N W	
8	10				
9	10	...	S E	N W	
10	10	...	S S E	N N W	
11	10	...	South	North	
12	10	...	S S W	N N E	
A.M.					
1	10	...	S W	N E	
2	11	...	W S W	E N E	
3	10	...	West	East	
4	10	...	W N W	E S E	
5	10	...	N W	S E	
6	10	...	N N W	S S E	
7	10	...	North	South	
8	10	...	N N E	S S W	
9	10	...	N E	S W	
10	10	...	E N E	W S W	Latitude by indifferent Observation 18° 2′ S.
11	10	...	East	West	Longitude, ditto, ditto ... ... 51° 2′ 30″ E.
12	10	...	E S E	W N W	
P.M.					*Wednesday 26th to Thursday 27th February.*
1	10	...	S E	N W	The horizon always obscure though sometimes clearing a little, but the squalls and sea always heavy ; pumped every hour. Two men at the helm. Always under bare poles. At 10 p.m. clearing up a little, and we saw some stars, but the sea and wind always heavy. Bent fore-topmast staysail, and fore and aft mainsail with two reefs in it. Bent another fore-topmast staysail on the forestay to balance the vessel's sails.* Scudding always according to the veering of the wind. Seeing that we had sustained much damage, and that we were nearer to Mauritius than to any other place, the Captain resolved to return there, not considering the vessel in a state to continue her voyage.
2	10	...	S S E	N N W	
3	9				
4	9				
5	9	...	South	North	
6	9	...	S S W	N N E	
7	10	...	W S W	E N E	
8	10	...	West	East	
9	10	...	N W	S E	
10	10	...	N N W	S S E	
11	10	...	North	South	
12	10	...	N N E	S S W	
A.M.					
1	10	...	N E	S W	
2	10	...	E N E	W S W	
3	10	...	East	West	
4	10	...	E S E	W N W	
5	10	...	S E	N W	Latitude Observation ... ... 20° 12′ S.
6	10	...	S S E	N N W	Longitude Chronometer ... ... 52° 24′ E.
7	10	...	South	North	
8	10	...	S S W	N N E	
9	10	...	S W	N E	
10	10	...	W S W	E N E	
11	10	...	West	East	
12	10				

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* *i.e.* When sail should be made, having lost the jib-boom.

Log of the Brig CHARLES HEDDLE.—*continued.*

H.	K.	F.	Courses.	Winds.	Remarks.
P.M. 1	7	...	S E	E N E	*Thursday 27th to Friday 28th February.*
2	7	...	S S E	Variable	The weather becoming fine, bent the foresail and spare fore-topsail, took the main-topsail yard for a mainyard, and let the reefs out of the fore and aft mainsail.
3	7	...	E S E	to N E	
4	7				
5	7				
6	6	4			Cloudy still, and lightning in all quarters.
7	6	4			Fine, and sea smooth with a pleasant breeze.
8	6	4			
9	6				
10	6				Latitude Observation ... ... 23° 19′ S.
11	6				Longitude Chronometer ... ... 54° 22′ 28′
12	6				At end of day.

It must be noticed that PIDDINGTON was indefatigable when he got hold of a log-book or a set of log-books that would illustrate the law of cyclones; and in respect to the log of the *Charles Heddle* he must have spent much time and labour—far more than it was worth--in determining in a variety of ways such results as it would give; but his main and most valuable achievement was the diagram of the ship's course from day to day, as shown in Fig. 13, p. 42,—which, no doubt, is approximately correct. The brig's course and distance by log was about N. 38° E. 102 miles, while the course and distance by D.R. and Obs. combined was S. 55° W. 370 miles; which would give a current or storm-wave running in the direction of S. 51° W., about 468 miles in five days, or at the average rate of about 4 miles per hour. But the log, on the face of it, and by comparing the courses, winds, and distance with the remarks, gives no sign of strict accuracy, notwithstanding PIDDINGTON's eulogy: it may be tried in a variety of ways, with an infinity of results—none satisfactory: the only fact that comes broadly out is, that in about the space of 120 hours, when scudding (according to the account) before the wind, the brig made five complete circuits of the compass—the 1st in 31 hours, the 2nd in 35 hours, the 3rd in 21 hours, the 4th in 17 hours, and the 5th in 16 hours—whether strictly before the wind, all the time, is however open to question. But one thing is certain, and which alone would confute the log, if the winds in the storm have circular motion, together with a general tendency (progression) towards the S.W.-ward, then (also of necessity) the resultant of the southerly and westerly courses must be in excess of that in any other direction, supposing a vessel to be running before the wind—and this too independently of any current. Log-books, kept in the ordinary way, are but a poor basis on which to found or establish a theory.

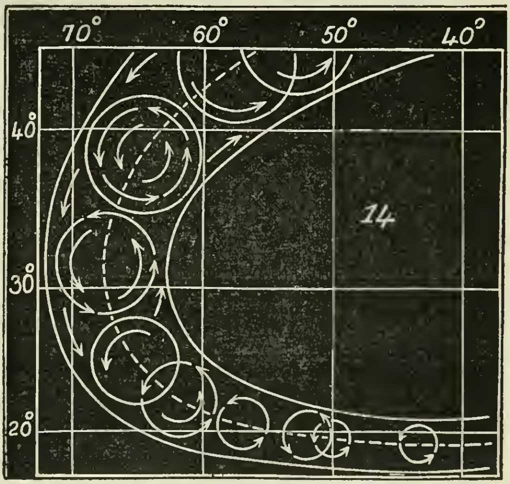
PRACTICAL RULES BASED ON THE CIRCULAR THEORY OF STORMS.

From whatever cause a steady wind is so obstructed as to produce a Hurricane, Typhoon or Cyclone, the wind then assumes a *rotatory* motion over an area varying from 20 or 30 to some hundreds of miles in diameter, revolving the more rapidly the nearer the centre or vortex, up to a certain distance, within which there is a *calm*; meanwhile the centre of rotation, together with the body of the storm, has a *progressive* motion varying from 2 to 30 or 40 miles per hour, with occasional intermitting intervals, during which it appears to be almost stationary, although the impetuosity of the wind itself around the circle may continue undiminished. Such storms have also been designated Revolving Storms.

Order of Rotation.—In the same hemisphere the *wind always revolves in the same way*, and that is *contrary to the apparent course of the sun;* hence this direction is opposite in opposite hemispheres, being from right to left in the northern, but from left to right in the southern hemisphere. Or, to use the familiar illustration of the hands of a watch laid face upwards,—the rotation of the wind during a hurricane, in the Northern Hemisphere, is in a direction contrary to that in which the hands move (Fig. 16, p. 49),—while in the Southern Hemisphere the rotation is in the same direction as that of the hands of a watch. (Fig. 17, p. 49.)

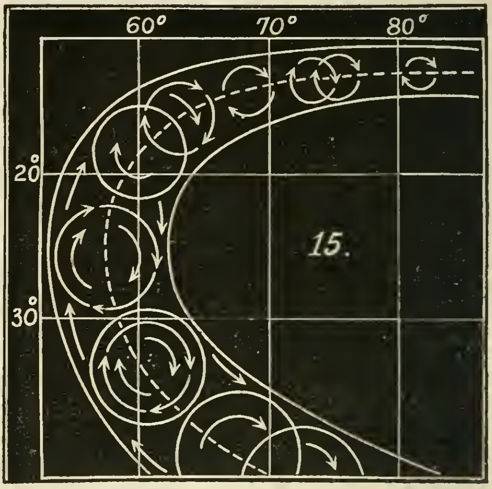
Progressive Movement.—The habitual tracks of hurricanes, if they have any, is unknown; but being prevalent alike in the three oceans—the Atlantic, Indian and Pacific—they follow at certain seasons tolerably definite routes, so that there must be few navigators who have never crossed the path of one. They are however rarely found within 6° to 8° of the equator, but they rage with most fearful violence in the tropical regions, and, as a rule, take a curved route approximating to a parabola.

In the Northern Hemisphere, commencing about lat. 10° to 20° N. the hurricane first advances from E.S.E., progressing towards W.N.W. with a northerly tendency as it approaches the northern tropic, where its course for some distance is nearly due North; somewhere in the vicinity of the parallel of 30° N. it *recurves*, and invading the extra-tropical regions, continues its progression,—advancing from S.W. towards the N.E.—increasing in diameter, while the wind, though still of fearful violence, has somewhat diminished in force as compared with its rotatory velocity while within the tropics, and so it moves onward, until it finally breaks up (Fig. 14). Such is especially the character of the West India hurricanes, which range between the parallels of 10° and 50° N., and between the meridians of 30° and 103° W., though the majority of them are included between 55° and 85° W. Some of those



that occur on the western side of the North Pacific affect the same form, while those off the coast of Mexico and Lower California merely take a N.W.-ly direction of comparatively small extent. The cyclones of the Bay of Bengal, and the Arabian Sea, as also the typhoons of China, generally take a straighter course, owing to local circumstances and the interference of the land.

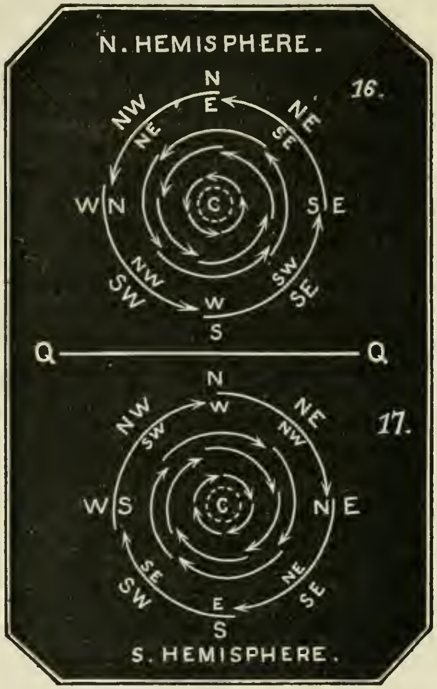
In the Southern Hemisphere, the cyclone, commencing in the equatorial region, first advances from E.N.E., progressing towards the W.S.W. with a more and more southerly tendency in approaching the southern tropic, in the vicinity of which its course is nearly due South; it then commences to *recurve*, and continues its progressive movement, advancing from N.W. towards S.E.,—expanding in dimensions and probably diminishing in force as it traverses the extra-tropical regions, until it finally disappears (Fig. 15). Cyclones occur in the Southern Indian Ocean between the N.W. coast of Australia and the northern end of Madagascar, and range from the parallels of 6° to 40° S.; but they are unknown in the South Atlantic. A few have been recorded in the South Pacific.



Deductions from the Order of Rotation.—Bearing in mind the direction of the rotation of the wind in each hemisphere, viz., against watch hands in the Northern, but with watch hands in the Southern, Hemisphere—certain portions of the storm will be characterized by certain hurricane winds; and considering the storm to be divided into four distinct parts, it will be found that, in the Northern Hemisphere, on the northern margin the wind must be *easterly;* on the eastern margin, *southerly;* on the southern margin *westerly;* and on the western margin, *northerly;* each portion of the cyclone possessing its appropriate wind. (*See* Fig 16.)

The relation of the winds to the margins in the Southern Hemisphere will be exactly the reverse of their relation in the Northern, owing to the reversion of the rotation; thus, it is the southern margin of the storm, south of the equator, that exhibits an *easterly;* the western margin, a *southerly;* the northern margin, a *westerly;* and the eastern margin, a *northerly* wind. (*See* Fig. 17.)

Also, as each portion of the hurricane has its appropriate wind, there results, according to the Law of the Rotation of Revolving Gales, a very simple *Rule for determining the bearing of the centre* of the storm from the ship—viz., *Look to the wind's eye, and set its bearing by compass,* —the EIGHTH *point to the* RIGHT *thereof, when in the Northern Hemisphere—but to the* LEFT *of the wind's direction when in the Southern Hemisphere—will be the bearing of the storm's centre.*



Hence, in the NORTHERN HEMISPHERE, from an *easterly wind* which characterizes the northern margin of the storm, its centre will bear *south;* from a *northerly* wind the centre will bear *east;* from a *westerly* wind it will bear *north;* and from a *southerly* wind, *west.* (*See* Fig. 16.)

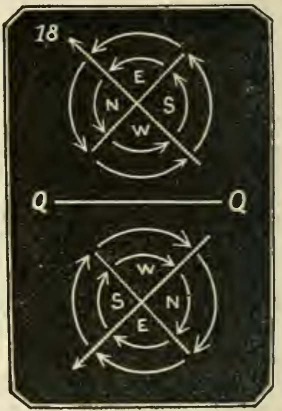
But, in the SOUTHERN HEMISPHERE, from an *easterly* wind, the centre of the storm bears *north;* from a *southerly* wind the centre bears *east;* from a *westerly* wind, *south;* and from a *northerly* wind, *west.* (*See* Fig. 17.)

It is characteristic of the hurricanes of both hemispheres that westerly winds are found on their equatorial side, and easterly winds on their polar side, throughout their entire course.

N.B.—In Figs. 16 and 17, the line Q Q represents the Equator, and the arrows (and the letters between them) show the direction of the wind for each hemisphere, according to the circular theory; the letters *outside* the arrows represent the points of the geographical horizon; C is the storm's centre; on this basis the two diagrams (16 and 17) fully illustrate the preceding paragraphs,—thus, in Fig. 16, on the N.E. side of the storm the wind will be S.E. and (when facing it) the centre will bear S.W., and similarly for the other points of the compass, so that Fig. 16 is a storm-compass for the N. hemisphere, and Fig. 17 a storm-compass for the S. hemisphere.

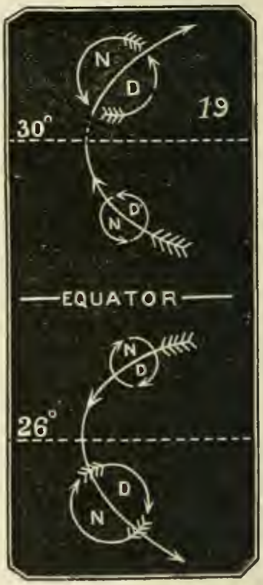
The line along which the centre of the hurricane progressively moves is variously called—the storm-path, the storm's track, and the axis-line; or, not inaptly, by the French, the trajectory—as indicative of a parabolic track in space. (*See* the dotted line in Figs. 14 and 15, pp. 47 and 48.)

A ship, in *front* of the storm, sailing, or lying-to, on the axis line would have no change of wind until the calm centre had passed over her, after which the wind would spring up suddenly with great fury from the opposite direction to that by which she had entered the centre.



For any given fixed point in the storm-field, the slower the progressive movement, the less rapid will be the change in the direction of the wind.

The axis line, or track of the hurricane, divides the storm-field into two parts, and, looking *towards* the direction in which the storm is moving, the part to the right is the *right-hand* semicircle, and that to the left is the *left-hand* semicircle. Another line, transverse to the axis line and passing through the calm centre, divides the storm-field into four quadrants, each of which has its characteristic predominant wind, as seen in Fig 18, and as already explained on p. 48.



French authors, speaking of the two sides of the storm-field, have applied the term "dangerous" (*dangereux*) to the semicircle in which the rotatory and progressive motion of the winds is approximately in the same direction; and the term "manageable" (*maniable*), or perhaps in this case better expressed as "navigable," to the semicircle in which the two motions are approximately opposed to each other. These two sides, in Fig. 19, are respectively designated by the letters D and N, and a glance at the long curved arrows, one north and the other south of the equator, which represent for each hemisphere the storm's track, shows that, in both hemispheres, the *dangerous* semicircle is *inside* or to eastward of the parabolic curve, and the *navigable* semicircle *outside* or to westward; or, in relation to right and left of the track, in opposite hemispheres the positions are reversed, thus—

In the Northern Hemisphere, the dangerous semicircle is to the right, and the navigable semicircle to the left, of the track: but,

In the Southern Hemisphere, the dangerous semicircle is to the left, and the navigable semicircle to the right, of the track.

Nor are the terms wholly inappropriate, for, if in the dangerous semicircle, running before the wind, the tendency is ever towards the axis line and the centre, but if in the navigable semicircle, except with bad management when in front of the storm, the tendency is ever away from the centre.

On this basis the *winds for each semicircle* are as follows :—

In the NORTHERN HEMISPHERE :—

Storm moving towards N.W.—

In dangerous semicircle, winds from N.E. to S.W. round by E. and S.

In navigable semicircle, winds from N.E. to S.W. round by N. and W.

Storm recurving to Northward.—

In dangerous semicircle, winds from E. to W. round by S.

In the navigable semicircle, winds from E. to W. round by N.

Storm moving towards N.E. —

In dangerous semicircle, winds from S.E. to N.W. round by S. and W.

In navigable semicircle, winds from S.E. to N.W. round by E. and N.

In the SOUTHERN HEMISPHERE :—

Storm moving towards S.W.—

In dangerous semicircle, winds from S.E. to N.W. round by E. and N.

In navigable semicircle, winds from S.E. to N.W. round by S. and W.

Storm recurving to Southward—

In dangerous semicircle, winds from E. to W. round by N.

In navigable semicircle, winds from E. to W. round by S.

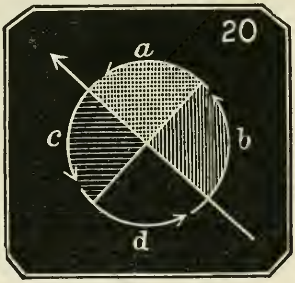
Storm moving towards S.E.—

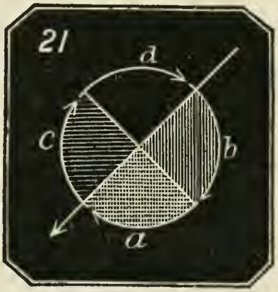
In dangerous semicircle, winds from N.E. to S.W. round by N. and W.

In navigable semicircle, winds from N.E. to S.W. round by E. and S.

But better still is the consideration of the storm-field, as divided into four quadrants, as in Figs. 20 and 21; from which it can readily be seen that the anterior quadrants (*a c*), *i.e.* those in front of the advancing centre, must, in each hemisphere, be more dangerous than the posterior (*b d*) ; while of the two anterior quadrants, since, in one of them the wind blows towards, and in the other away from, the axis line—

The advancing quadrant (Fig. 20 *a.*) *of the right-hand semicircle in the Northern Hemisphere, but the advancing quadrant* (Fig. 21 *a*) *of the left-hand semicircle in the Southern Hemisphere, must be the* MOST DANGEROUS— in which, if a ship be put before the wind, she must inevitably approach nearer and nearer to the storm's track and centre ; but this be it observed, is a manœuvre only justifiable in the case of the vessel being on the verge of the storm, and so near the axis line that she can speedily cross it, and thus be brought into the safer of the two advancing quadrants. The posterior quadrants can never come down on a vessel, but, with plenty of sea-room, may be entered, and the winds turned to advantage.





The storm paths over the Atlantic Ocean are characterized by *certain winds* that are *most dangerous* to vessels falling in with them—according to the locality—as follows :—

(1.) Before recurving—off the West India Islands—the most dangerous hurricane winds are those between E.N.E. and N.N.E.

(2.) About the period of recurving, vessels off the Bahamas and the coast of Florida find E., E.S.E., and S.E. winds most dangerous.

(3.) After recurving, vessels off the coast of the United States find E.S.E. to S.S.E. and S. winds most dangerous.

In the Southern Indian Ocean, if the cyclone be moving towards the S.W. the most dangerous winds are those between S. and E. ; but when moving towards the S.E., winds between the E. and N. are the most dangerous. At the period of recurving, winds between N.E. and S.E. are most dangerous.

So that in both hemispheres winds inclining to westerly are comparatively safe, while such as have easting in them require caution, skill and judgment in manœuvring the ship, under whatever circumstances she encounters them—whether by running into, or being overtaken by, a hurricane.

Use of the Barometer.—It was a trite observation of PIDDINGTON's that "he who watches his Barometer watches his ship." This invaluable instrument, if well understood and *watched*, invariably announces the approach of a revolving storm,—shows whether the vessel is plunging into the vortex, or if she be receding from it—and hence, by carefully noticing its indications, the disastrous consequences of a hurricane may, to a great extent, be avoided, for the laws of its oscillations are appreciably characteristic and very distinctly marked. The barometer often stands unusually high *before* the commencement of a hurricane, and frequently (if not always) just *around* the storm; and conceiving the hurricane to be divided, as before, into two parts by a diameter at right angles to its track, it may be noted that in both hemispheres—

(*a*) The barometer always *falls* during the passage of the *advancing* semicircle of a revolving storm ; and again—

(*b*) The barometer always *rises* during the passage of the *receding* semicircle of a revolving storm :—

hence, in cases of manœuvring to take advantage of hurricane winds and to keep just within the verge of the storm, the barometer is of signal benefit; it should be kept as high as possible without losing the wind. When sailing *from* the vortex the barometer will *rise;* when sailing *towards* the vortex it will *fall;* and if, after having fallen considerably, it rises—at first rapidly, and then gradually—such rising indicates that the first (or dangerous) half of the storm has passed away.

Tack on which to heave-to.—When involved in a hurricane, in the Northern Hemisphere, if the ship is on the starboard tack her head is directed from the centre ; but if on the port tack, her head is towards the centre. In the Southern hemisphere, as a necessary consequence of the rotation of the wind, the conditions are reversed, and thus the starboard tack leads towards, and the port tack from, the centre of the storm. But nevertheless, as a general rule, since it is advisable to heave a ship to so that she may come up to the wind as it shifts, the rule will be,—*in both hemispheres*—

(*a*) When in the *right-hand* semicircle heave-to on the *starboard* tack ; but—

(*b*) When in the *left-hand* semicircle heave-to on the port tack.

Running is never recommended, except as a necessity.

The Storm Wave.—The rotation of the wind in a hurricane violently agitates the surface of the ocean in the direction of the wind, producing a *swell* or STORM WAVE, the undulations of which roll to an extraordinary distance, behind, before, and on each side of the storm. As the wind is continually veering, there results a *series* of undulations, producing in the area of intersection *cross seas* more or less dangerous. Such a series of undulations must always *fringe* the storm's wake, and be found to the right and left of the path over which the hurricane has advanced ; while the long rolling swell generally precedes it, and thus indicates the approach of the storm many hours—if not a day—before it is encountered by the ship.

The *area* that rotatory storms have been estimated to cover varies from 30 or 40 to 1000 miles ; but while the diameter, so long as the storm is within the tropics, expands but very gradually, it suddenly increases in dimensions with remarkable rapidity after recurving. The *rate at which they travel* on their onward course also varies greatly, not only in different parts of the globe, but even in the same locality, and at the same season. Generally, however, the velocity with which the vortex of the hurricane progresses is greater as the storm recurves on approaching the outer edge of the trade-winds. According to REDFIELD, the hurricane of August, 1853, traversed 7276 English miles in about 12 days, with a mean progessive velocity of 26 miles per hour ; but after it had arrived at the banks of Newfoundland, this velocity was increased to about 50 miles per hour.

Within the area of the storm the wind has been estimated to attain, on frequent occasions, a rotatory velocity of from 70 to 100 miles an hour, and even more within the tropics.

Tables I., II., III. and IV. (pp. 54—56) give the *various methods of manœuvring*, according to the direction of wind and bearing of centre (on the circular theory): the headings of the columns sufficiently explain the use of the Tables :—It may be stated that I. and II. are given by DOVE following Capt. SEDGWICK ; III. and IV. are given on French authority, and in these N=navigable semicircle, D=dangerous semicircle, P=port tack, and S=starboard tack.

I. FOR NORTH HEMISPHERE (*Dové.*)

Direction of Wind at commencement of Storm.	Bearing of Centre.	If the Wind shifts from		Steer		But if the Wind shifts from		
N.W.	N.E.	N.W.	towards W.	S.E.	Or, otherwise, heave to, on Port Tack.	N.W.	towards N.	Heave to, on Starboard Tack.
N.W. by N.	N.E. by E.	N.W. by N.	„ W.	S.E. by S.		N.W. by N.	„ N.	
N.N.W.	E.N.E.	N.N.W.	„ W.	S.S.E.		N.N.W.	„ N.	
N. by W.	E. by N.	N. by W.	„ W.	S. by E.		N. by W.	„ N.	
N.	E.	N.	„ W.	S.		N.	„ E.	
N. by E.	E. by S.	N. by E.	„ N.	S. by W.		N. by E.	„ E.	
N.N.E.	E.S.E.	N.N.E.	„ N.	S.S.W.		N.N.E.	„ E.	
N.E. by N.	S.E. by E.	N.E. by N.	„ N.	S.W. by S.		N.E. by N.	„ E.	
N.E.	S.E.	N.E.	„ N.	S.W.		N.E.	„ E.	
N.E. by E.	S.E. by S.	N.E. by E.	„ N.	S.W. by W.		N.E. by E.	„ E.	
E.N.E.	S.S.E.	E.N.E.	„ N.	W.S.W.		E.N.E.	„ E.	
E. by N.	S. by E.	E. by N.	„ N.	W. by S.		E. by N.	„ E.	
E.	S.	E.	„ N.	W.		E.	„ S.	
E. by S.	S. by W.	E. by S.	„ E.	W. by N.		E. by S.	„ S.	
E.S.E.	S.S.W.	E.S.E.	„ E.	W.N.W.		E.S.E.	„ S.	
S.E. by E.	S.W. by S.	S.E. by E.	„ E.	N.W. by W.		S.E. by E.	„ S.	
S.E.	S.W.	S.E.	„ E.	N.W.		S.E.	„ S.	
S.E. by S.	S.W. by W.	S.E. by S.	„ E.	N.W. by N.		S.E. by S.	„ S.	
S.S.E.	W.S.W.	S.S.E.	„ E.	N.N.W.		S.S.E.	„ S.	
S. by E.	W. by S.	S. by E.	„ E.	N. by W.		S. by E.	„ S.	
S.	W.	S.	„ E.	N.		S.	„ W.	
S. by W.	W. by N.	S. by W.	„ S.	N. by E.		S. by W.	„ W.	
S.S.W.	W.N.W.	S.S.W.	„ S.	N.N.E.		S.S.W.	„ W.	
S.W. by S.	N.W. by W.	S.W. by S.	„ S.	N.E. by N.		S.W. by S.	„ W.	
S.W.	N.W.	S.W.	„ S.	N.E.		S.W.	„ W.	

II. FOR SOUTH HEMISPHERE (*Dové*)

Direction of Wind at commencement of Storm.	Bearing of Centre.	If the Wind shifts from		Steer		But if the Wind shifts from		
S.	E.	S.	towards W.	N.	Or, otherwise, heave to, on Starboard Tack.	S.	towards E.	Heave to, on Port Tack.
S. by E.	E. by N.	S. by E.	„ S.	N. by W.		S. by E.	„ E.	
S.S.E.	E.N.E.	S.S.E.	„ S.	N.N.W.		S.S.E.	„ E.	
S.E. by S.	N.E. by E.	S.E. by S.	„ S.	N.W. by N.		S.E. by S.	„ E.	
S.E.	N. E.	S.E.	„ S.	N.W.		S.E.	„ E.	
S.E. by E.	N.E. by N.	S.E. by E.	„ S.	N.W. by W.		S.E. by E.	„ E.	
E.S.E.	N.N.E.	E.S.E.	„ S.	W.N.W.		E.S.E.	„ E.	
E. by S.	N. by E.	E. by S.	„ S.	W. by N.		E. by S.	„ E.	
E.	N.	E.	„ S.	W.		E.	„ N.	
E. by N.	N. by W.	E. by N.	„ E.	W. by S.		E. by N.	„ N.	
E.N.E.	N.N.W.	E.N.E.	„ E.	W.S.W.		E.N.E.	„ N.	
N.E. by E.	N.W. by N.	N.E. by E.	„ E.	S.W. by W.		N.E. by E.	„ N.	
N.E.	N. W.	N.E.	„ E.	S.W.		N.E.	„ N.	
N.E. by N.	N.W. by W.	N.E. by N.	„ E.	S.W. by S.		N.E. by N.	„ N.	
N.N.E.	W. N. W.	N.N.E.	„ E.	S.S.W.		N.N.E.	„ N.	
N. by E.	W. by N.	N. by E.	„ E.	S. by W.		N. by E.	„ N.	
N.	W.	N.	„ E.	S.		N.	„ W.	
N. by W.	W. by S.	N. by W.	„ N.	S. by E.		N. by W.	„ W.	
N. N. W.	W. S. W.	N.N.W.	„ N.	S.S.E.		N.N.W.	„ W.	
N.W. by N.	S.W. by W.	N.W. by N.	„ N.	S.E. by S.		N.W. by N.	„ W.	
N.W.	S.W.	N.W.	„ N.	S.E.		N.W.	„ W.	

III. FOR NORTH HEMISPHERE. (*From the French.*)

Direction of Wind.	Bearing of Centre.	Cyclone moving N W-ly.			Cyclone moving N-ly.			Cyclone moving N E-ly.		
		Semicircle in which Ship takes cyclone.	Tack on which to heave-to.	Course (if possible) to run out of cyclone.	Semicircle in which Ship takes cyclone.	Tack on which to heave-to.	Course (if possible) to run out of cyclone.	Semicircle in which Ship takes cyclone.	Tack on which to heave-to.	Course (if possible) to run out of cyclone.
N	E	N	P	S W	N	P	S W	N	P	S W
N by E	E by S	...	...	SWbyW	...	...	S WbyW	...	...	S W
N N E	E S E	...	...	W S W	...	...	W S W	...	...	S W
N E by N	S E by E	...	...	W by S	...	...	W by S	...	..	SW by W
N E	S E	D	S	W	...	...	W	...	...	W S W
N E by E	S E by S	...	...	W by N	...	...	W by N	...	...	W by S
E N E	S S E	...	...	W N W	...	...	W N W	...	...	W
E by N	S by E	...	...	W N W	...	...	N WbyW	...	...	W by N
E	S	...	...	W N W	D	S	N W	...	...	N W
E by S	S by W	...	...	NW byN	...	...	NWbyN	...	...	NW by N
E S E	S S W	...	...	N N W	...	...	N N W	...	...	N N W
S E by E	S W by S	...	...	N by W	...	...	N N W	...	...	N by W
S E	S W	...	...	N	...	...	N N W	D	S	N
S E by S	S WbyW	...	...	N by E	...	...	N by E	...	...	N by E
S S E	W S W	...	...	N N E	...	...	N N E	...	...	N N E
S by E	W by S	...	...	N E by N	...	..	NE by N	...	...	NN E
S	W	...	...	N E	...	...	N E	...	...	N N E
S by W	W by N	...	...	N E by E	...	...	N E by E	...	...	N E by E
S S W	W N W	...	...	E N E	...	...	E N E	...	...	E N E
S W by S	NWbyW	...	...	E by N	...	...	E by N	...	...	E by N
S W	N W	...	...	E	...	...	E	...	...	E
S WbyW	NWbyN	N	P	E by S	...	...	E by S	...	...	E by S
W S W	N N W	...	...	E S E	...	...	E S E	...	...	E S E
W by S	N by W	...	...	S E by E	...	...	S E by E	...	...	S E by E
W	N	...	...	S E	...	...	S E	...	...	S E
W by N	N by E	...	...	S E by S	N	P	S E by S	...	...	S E by S
W N W	N N E	...	...	S S E	...	...	S S E	...	...	S S E
N WbyW	N E by N	...	...	S by E	...	...	S by E	...	...	S by E
N W	N E	...	...	S	...	...	S	...	...	S
N W by N	N E by E	...	...	S by W	...	...	S by W	N	P	S by W
N N W	E N E	...	...	S S W	...	...	S S W	...	...	S S W
N by W	E by N	..	...	S W by S	...	...	S W by S	...	...	S W by S

IV. FOR SOUTH HEMISPHERE. (*From the French*)

Direction of Wind.	Bearing of Centre.	Cyclone moving S W-ly			Cyclone moving S-ly			Cyclone moving S E-ly		
		Semicircle in which Ship takes cyclone.	Tack on which to heave-to.	Course (if possible) to run out of cyclone.	Semicircle in which Ship takes cyclone.	Tack on which to heave-to.	Course (if possible) to run out of cyclone.	Semicircle in which Ship takes cyclone.	Tack on which to heave-to.	Course (if possible) to run out of cyclone.
N	W	D	P	S E	D	P	S E	D	P	S S E
N by E	W by N	...	...	S E by S	...	...	S E by S	...	...	S S E
N N E	W N W	...	...	S S E	...	...	S S E	...	...	S S E
N E by N	NW by W	...	...	S by E	...	...	S by E	...	...	S by E
N E	N W	...	...	S	...	...	S S W	...	...	S
N E by E	NW by N	...	...	S by W	...	...	S S W	N	S	S by W
E N E	N N W	...	...	S S W	...	...	S S W	...	...	S S W
E by N	N by W	...	...	S W by S	...	...	S W by S	...	..	SW by S
E	N	...	...	W S W	...	...	S W	...	...	S W
E by S	N by E	...	...	W S W	N	S	SW by W	...	...	SW by W
E S E	N N E	...	...	W S W	...	...	W S W	...	...	W S W
S E by E	NE by N	...	...	W by S	...	...	W by S	...	...	W by S
S E	N E	...	...	W	...	...	W	...	...	W
S E by S	N E by E	N	S	W by N	...	...	W by N	...	...	W by N
S S E	E N E	...	...	W N W	...	...	W N W	...	...	W N W
S by E	E by N	...	...	NW by W	...	...	NW by W	...	...	NW by W
S	E	...	...	N W	...	...	N W	...	...	N W
S by W	E by S	...	...	NW by N	...	...	NW by N	...	...	NW by N
S S W	E S E	...	...	N N W	...	...	N N W	...	...	N N W
S W by S	S E by E	...	...	N by W	...	...	N by W	...	...	N by W
S W	S E	...	...	N	...	...	N	D	P	N
SW by W	S E by S	...	...	N by E	...	...	N by E	...	...	N by E
W S W	S S E	...	...	N N E	...	...	N N E	...	...	N N E
W by S	S by E	...	...	NE by N	...	...	N E by N	...	...	N E by N
W	S	...	...	N E	D	P	N E	...	...	N E
W by N	S by W	...	...	N E by E	...	...	NE by E	...	...	N E by E
W N W	S S W	...	...	E N E	...	...	E N E	...	...	E N E
N W by W	SW by S	...	...	E by N	...	...	E by N	...	...	E by N
N W	S W	D	P	E	...	...	E	...	...	E
NW by N	SW by W	...	...	E by S	...	...	E by S	...	...	E by S
N N W	W S W	...	...	E S E	...	...	E S E	...	...	E S E
N by W	W by S	...	...	S E by E	...	...	S E by E	...	...	S E by E

Heaving-to will always be dangerous when in front of the cyclone and near the axis line, and having reason to believe the ship is in that position, avoid heaving-to under the following circumstances, unless compelled to do so :—

When in the Northern Hemisphere—

Storm moving N.W.-ly, winds between N.N.E. and E.N.E.
Storm recurving, winds between E.N.E. and E.S.E.
Storm moving N.E.-ly, winds between E.S.E. and S.S.E.

When in the Southern Hemisphere—

Storm moving S.W.-ly, winds between S.S.E. and E.S.E.
Storm recurving, winds between E.S.E. and E.N.E.
Storm moving S.E.-ly, winds between E.N.E. and N.N.E.

General Rule.—The elder cyclonologists were very cautious about giving rules for manœuvring ; those on pp. 54-56 are of comparatively recent origin. Their rules may be summarized as follows—heave-to for the first hour to two (when overtaken by a cyclone) to determine your position in the storm, by noting the changes of wind and state of barometer; then, if it be deemed safe to stand on, do so.; should bad weather increase, with a falling barometer, heave-to again, and so continue, until new changes indicate that standing on may once more be attempted ; if, having done so, there is no improvement, exercise your own judgment as to heaving-to a third time.

PIDDINGTON was wise in his generation, but far too severe a critic, for it is often easy to see, after the event, how misadventure has occurred ; but none of the cyclonologists ever wrote more practical directions than he did, when in later days he penned the following :—ALL POSITIVE *rules for manœuvring are sheer nonsense, and only tend to mislead : every ship in every cyclone must have its own peculiar management, dependent on the four great elements of the problem, which are*—(1) *the ship and her sea-room ;* (2) *the track of the cyclone ;* (3) *its rate of travelling ; and* (4) *the ship's run and drift :* while on the part of the commander, caution and watchfulness are essentially requisite.

The meteorological signs that herald the approach of, and that usually accompany, a hurricane or cyclone have been carefully collected from various sources by Mr. W. R. BIRT, and a summary of them is given in his " Handbook of the Law of Storms ; " in enumerating and collating them he has classified them under several distinct and characteristic headings, as follows :—

" Meteorological signs recognised by the feelings—

1. A sultry, oppressive state of the atmosphere.
2. A calm.

" Meteorological signs recognized by the eye—

3. A remarkably clear state of the atmosphere, so that the stars

may be seen to rise and set with nearly the same distinctness as the sun and moon.

4. A peculiar white appearance in the zenith, more or less of a circular form.

5. A remarkably red or fiery appearance of the sky.

(This is not unfrequently of such intensity as to tinge all surrounding objects with a deep crimson; and when this is observed, there can be no question that the violent portion of the cyclone is not far from the vessel. When this red light is seen at night, the impression on the seaman's mind is, that 'day has broken before its time.'

6. A peculiar colouring of the clouds, more especially of an olive green.

(This is generally the precursor of a most violent and terrific hurricane.)

7. A thick, hazy appearance in that quarter of the horizon in which the cyclone is raging.

8. A remarkable and peculiar appearance of the heavenly bodies. When shining through a haze, they are said to shine with a pale sickly light, and are not unfrequently surrounded by rings of light, or halos. Some observers describe the stars as 'looking big with burrs about them.' Others speak of their dancing, and generally, they have been noticed as being remarkably bright and twinkling.

9. The sun on some occasions has exhibited a blue appearance, and white objects have been seen of a decided light-blue colour. The sun has also been observed of a pale and somewhat similar appearance to that of the full moon.

10. A dense heavy bank of cloud in the direction of the hurricane.

11. A peculiar appalling appearance in this bank, more particularly as if it were a solid wall drawing down upon and closing around the ship.

12. A darting forward of portions of this bank, as if torn into rags and sheds by some violent force, and driven before, *not borne* by, the wind. (When this indication is distinctly recognized, a run of about two hours *towards the centre* will involve the vessel in a destructive hurricane.)

13. A peculiar motion exhibited by small bodies, as branches of trees, when agitated by the wind, consisting of a sort of whirling, *not a bending forward, as if bent by a stream of air.*

14. Lightning of a remarkably columnar character, shooting up in stalks from the horizon with a dull glare; also like flashes from a gun, and sparks from a flint and steel.

"Meteorological signs recognised by the ear—

15. A distant roar (probably of the hurricane itself), as of wind rushing through a hollow vault.

16. A peculiar *moaning* of the wind, indicative of the close proximity of the violent portion of the hurricane.

"The meteorological phenomena accompanying a revolving storm may also be enumerated thus:—

1. A very rapid motion of the air, constituting the hurricane, and increasing in velocity as the centre is approached.

2. A fitful variation of intensity, in the force of the wind, which sometimes blows with fearful violence, carrying away everything that opposes its progress, then sinking to a gentle breeze, or even lulling to a calm, but almost immediately afterwards springing up with greater violence than before. The hurricane winds are nearly, if not entirely, without exception puffy, violent, and blowing in gusts.

3. An immense condensation of aqueous vapour, forming large banks of cloud, which precipitate torrents of rain. The condensation appears to be so exceedingly rapid that large quantities of electricity are generally developed, giving rise to incessant flashes of lightning.

4. A general darkness and gloominess within the area of the cyclone, relieved only by the fitful glare of the lightning, or the appearance of the imperfect circle of light near the centre or axis of the storm.

5. A separation of the clouds in or near the centre of the hurricane, so as to produce in the immediate neighbourhood of the axis a clear sky, through which the sun and stars are often seen with great brilliancy.

6. A calm in the centre of the cyclone.

"Indications of approaching or existing hurricanes manifested by the ocean, of especial utility to vessels at anchor in roadsteads, &c. :—

1. A swell produced by the storm-wave rolling in upon the shore, at first of a gentle character. The direction of this swell will pretty surely indicate the bearing of the storm, and its changes will point out, in some localities, the course the hurricane may be pursuing.

2. A swell rolling in, *without changing its direction*, may be regarded as indicative of a hurricane *approaching* the shore. The same phenomenon met with at sea (the ship's course being taken into account), will indicate the bearing down of the cyclone on the vessel.

3. A dirty green appearance of the ocean ; on some occasions its assuming a muddy or brown colour, on others its being remarkably clear ; its temperature increasing, and its smelling stronger than at other times, are all indications of the proximity of a cyclone."

The Mauritius Meteorological Society, for years after its establishment, were constantly discussing the improbabilities of many of the "well-established laws" and the errors of some of the "practical rules :" the subject, though ever recurring, was always fresh, for every season brought disabled ships to Port Louis to refit ; all sorts of forms for the cyclone, novel modes of progression, and new rules for avoiding the fury of the tempest were constantly before the members, and their value debated with considerable vigour : the perception of a theory differing from the circular one had dawned on them years before much notice was taken of their "Proceedings" in Europe, and in 1861 the controversy was at its height. Mr. C. MELDRUM, the secretary, had (during ten or a dozen years) often called attention to the apparent incurving of the wind in cyclones, and to the losses occasioned by masters of ships acting on the supposition that the bearing of the centre of the storm was at right angles to the direction of the wind, and that the movement of the wind was in concentric circles: he had come to the conclusion that there was a converging of the wind in cyclones, when the late Capt. DOUGLAS WALES, then harbour-master at Port Louis, addressed the following important letter to him in 1872:—

"Some remarks of yours respecting the uncertainty of the real position of the centre of a cyclone set me thinking, and I send you a few ideas on the subject, which, as a sailor, I think worthy the serious attention of seamen, and the correctness of which they may put to the test of experience, whenever they have opportunities of doing so.

"Allow me to premise that I have no intention of dogmatizing. I believe our knowledge of the causes of these fearful tempests, of their origin, their progress in this or that direction, their rate of progression, their recurving, the reason of those recurvings, and their ultimate dispersion, to be still in its infancy. No doubt, the knowledge already acquired has saved many a good ship from becoming entangled in these storms, especially ships approaching them on their equatorial sides; but at the same time it must be admitted that more than one intelligent seaman, who thought himself well up in the subject, has actually run into the very centre of a cyclone, when, by all known rules, he ought to have been certain of avoiding it.

"There must be some reason for such an error, and it is that reason that I have been seeking for, and which, I trust, I have to some extent discovered. I assume that within a diameter of 40, 50, 60, 70, or 80 miles a true circular storm of terrific violence must be found in every so-called hurricane, and that to a considerable distance outside and around this central and circular storm winds are to be found gradually decreasing in force from 11, near the outer edge of the central storm, to 7 and 6, at the outer edge of the bad weather, but which, instead of blowing in ever enlarging circles further and further out from one common centre, are always converging to that centre, and on all sides gradually increasing, until, at a certain distance from the central calm, they acquire the force of a hurricane (12), and thence *inwards* blow with great violence in what, in all probability, is as nearly as may be a circle.

"It is these converging lines of wind that are, I think, likely to lead men into error as to the position of the centre of the storm.

"I shall, to prevent confusion, confine myself to cyclones south of the equator, every one acquainted with the cyclonic theory knowing that the inverse of rules for the guidance of seamen in the southern hemisphere will be the rules for their guidance in the northern hemisphere.

"Let us suppose that a ship bound to Europe arrives at a point in a converging curve where the wind being N.E. with force 7, that is, double reefs and jib,—barometer falling, sky overcast, confused swell, and, in short, every appearance of bad weather;—Lat. 12° S., Long. 70° E.—

What ought her Commander to do? 'Heave-to on the Port Tack,' says one, 'and wait for the weather to clear.' 'Run to the S.W.,' says another, 'and make use of the storm.' Being a pushing fellow he makes up his mind to run, and, truth to say, there are as many reasons for approving that proceeding as for finding fault with it.

"If he succeeds in making use of the hurricane he is considered a smart fellow; if he runs into it and is dismasted, or worse, 'rash,' 'headstrong,' 'ignorant', &c.,* are the best terms he can look for: and yet he might as easily have been wrong in heaving-to as in running.

"The wind being N.E. he infers that the centre bears N.W. (*see* diagram 17, p. 49.) He considers that the barometer and weather indicate that he is on the S.E. edge of a cyclone—the N.E. wind upon which he is running forming a part of a *circular* storm, and that necessarily the centre is N.W. of him. Considering, further, that in that Lat. and Long. the storm is probably travelling W.S.W., he thinks that if he runs S.W. he will be diverging from it, and that by making use of the storm. he will get fine runs, perhaps for days to come.

"But if the N.E. wind be only converging towards the fearful storm raging near the centre, that centre, in the first place, bears W. by N. ½ N. instead of N.W., so that the vessel, by steering S.W., is not diverging from the centre, as supposed, but is really drawing nearer to it. In due time the weather gets worse from this very cause; the wind veers more to the eastward; the barometer continues to fall; and the Captain begins to doubt whether the storm may not after all be progressing more to the southward than he supposed—whether indeed it may not, although so far to the eastward, be actually recurving, and he naturally becomes anxious, and uncertain what to do. If he decides on running at all risks, he finds the wind still drawing at first more and more easterly, and then more and more southerly, always increasing in fury, and the sea becoming more and more heavy and tumultuous. But run he must now, and he must run dead before it, and being on what I have supposed a line of wind converging to a centre he finishes by getting into the real hurricane, and loss and disaster are imminent. He may, however, if his ship be tight and staunch, and runs well, get round to the N.W. side of the storm, and so get clear, probably with loss of spars and sails; but he has clearly run into what he was running to avoid, because he was under the impression that the winds within the influence of a cyclone, although far from its centre, blew in *circles* round that centre, the wind everywhere clearly indicating the exact, or nearly exact, position of that centre.

"These opinions I submit with very great diffidence for the consideration of seamen and cyclonists. I am not going to attempt the setting up of any dogmatic theory of mine own, but I am inclined to think that this theory of converging winds will probably account for the manner in which many vessels have become entangled in hurricanes when seeking to avoid them according to cyclonic rules. Like all other theories on this very important subject, it requires very careful consideration; but there can be no possible risk in deducing from it the *rule* that vessels on approaching what the barometer, the state of the weather, and the force of the wind, clearly indicate as the dangerous side of a cyclone, should, in seeking to avoid it, *keep the wind quite four points on the Port Quarter.*

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* These expressions are mild as compared with some that were heaped on shipmasters who (following, as they thought, "definite and unambiguous rules") had the misfortune to find their way to the centre, instead of out, of the hurricane.

"With the wind thus free, a fast ship would run with great rapidity through the water, and, unless the storm were advancing on her in a direct line, would be always increasing her distance from its centre, and getting into finer weather—and, in any case, would have a very good chance of running across its track, and thus avoiding it.

"Ships running into cyclones on their equatorial sides are to a very great extent without excuse. There are, however, some exceptional instances; but they are very rare."

The Theory of Revolving Storms had passed into what was supposed to be a well-defined Law, and the Practical Rules deduced therefrom were taken as established on the very best basis—that of experience: it may, however, be said, without misstatement, that, from a critical point of view, the *circular* theory had come to be accepted without much controversy;—true, it had at first encountered opposition; but from some cause, whether from the influence of names (always very potent), or from the apparent simplicity of the "Law" and its deductions, the opposition had been silenced, or was in abeyance. Now no place, better than the Mauritius, owing to its situation, could have been selected for a crucial examination—at once of the theory and its practical bearing on navigation; and the letter of Capt. Wales is important, as showing that the regular discussions of the Meteorological Society of the island were (in 1872) beginning to develop valuable and unexpected results. There were advocates of the circular theory, and others who strongly opposed it, and the discussions were at times very animated; the form of cyclones—whether circles or ellipses; the calm—was it in the centre of a circle, or in one of the foci of an ellipse?—were the winds at a given place in the storm from such direction as the theory required them to be?—did this or that ship run into the vortex through disregarding or obeying the practical rules?—these had been the topics debated and discussed at almost every meeting of the Society for ten or twelve years: meanwhile the Secretary (Mr. C. Meldrum) was quietly examining the archives for new data; the investigation resulted in his faith in the old principles being gradually shaken; and in February 1873 he read to the Society the following important paper:—

Notes on the Form of Cyclones in the Southern Indian Ocean, and on some of the Rules given for avoiding their Centres.

"According to the earlier writers on the 'Law of Storms,' cyclones are of a circular form, and they are invariably represented by a number of concentric circles, in which the wind in the Northern Hemisphere blows from right to left, or against the hands of a watch, and in the contrary direction in the Southern Hemisphere.

" Following in the footsteps of his predecessors, who had written some 30 years previously, M. BRIDET, in his excellent treatise, *Etude sur les Ouragans* (Paris, 1869), has adopted the same views.

" Now, if cyclones are circular, it is very easy to know the bearing of the centre, and a very simple rule is laid down by cyclonologists for the guidance of shipmasters in that respect. ' Turn your face to the wind,' they say, ' and if you are in the Northern Hemisphere, the centre will be ' to your right, but, if in the Southern Hemisphere, to your left.' Or ' the bearing of the centre is always at right angles to the direction of ' the wind, but in different directions in the two hemispheres.' Thus, with the wind at East, the centre in the Northern Hemisphere bears due South, and in the Southern Hemisphere due North ; and so on.

" But it is evident that if cyclones are *not* circular, the above rule is inapplicable. It is, therefore, of great practical importance to know something of the form of cyclones.

" The first time attention was called to this particular point, was, so far as I can find, in January, 1860. The winds and weather at the Mauritius Observatory had just indicated the passage of a cyclone, and I determined to deduce its track from my own observations alone, before any vessels could arrive. Proceeding on the supposition that the circular theory was correct, I was obliged to come to the conclusion ' that the ' E.S.E. wind, which blew for 48 hours, did not belong to the cyclone, ' unless the latter travelled at first S. by E. and S.S.E., and then S. by ' W. and S.S.W., or in some other irregular way.'

" These remarks, which were published in the *Commercial Gazette*, attracted the attention of Mr. CLARE BERNARD.

" ' At the end of last January,' remarks Mr. BERNARD in a paper which he communicated to the Society, ' I saw with great interest, in ' the *Commercial Gazette*, the remarkable paper read by Mr. MELDRUM ' to the Meteorological Society on the cyclone of the 8th to 16th ' January, and the perusal of it directed my ideas towards cyclonology. ' to which I had hitherto paid but little attention.

" ' Soon afterwards I met with an extract from the *Archives* of ' Mauritius, containing an account of the celebrated hurricane of 1818, ' and I was anxious to trace the track which this cyclone had taken. I ' did so according to the circular theory, following the method described ' by Mr. MELDRUM in his paper, and was much surprised to find myself ' confronted by an impossible result. For the wind in 1818 commenced ' at E.S.E., which placed the centre of the cyclone to the N.N.E. ; it ' afterwards veered to South, thus placing the centre in the East, it then ' veered to North and N.W., which made the centre pass to the West' ward, and S.W.-ward of Mauritius. This cyclone, therefore, had travelled ' in a zig-zag direction.'

" Mr. BERNARD then proceeds to develope a theory by which, on the supposition that cyclones are elliptical, that the centre is in the posterior focus of the ellipse, and that the inclination of the major axis to the meridian varies, he accounted for all anomalies. But it was evident that, without further observation, this ingenious theory would not be sufficient to overthrow the circular theory, which had held its ground for nearly 30 years. (*See* Mercantile Marine Magazine, Vol. 10, p. 321.)

" From January, 1860, down to the present time, no hurricane has been examined here which has not afforded fresh evidence that cyclones are not so circular as they have been supposed to be. To reproduce all the remarks that have been made on the subject would occupy too much time and space, but it may be proper to remind the Society of some of them.

" In a paper read on the 31st July, 1860, giving an account of the hurricane of the 6th to the 17th February, 1860, it is said:—'The 'Southerly and Northerly winds extended many degrees South and 'North of the centre, giving the storm an elliptical appearance ; and on 'at least the 11th, 12th and 13th, the trade, at some distance to the 'Eastward, was directed towards the centre. Hence the bearing of the 'centre, from many of the vessels was not at right angles to the wind's 'direction.'

" The following quotation is from an account of the hurricanes of the 18th to the 29th February, 1860 :—' There are no means of determining 'the exact forms of the cyclones on each day ; but it is evident that the 'wind did not blow in true circles. From observations made on all sides 'of the *Phœnix* storm, on the 25th, it would appear that the meteor had 'a helical form : for, while the S.E. trade swept round on its Western 'side, and the N.W. monsoon on its Eastern side, in two distinct curves, 'there was an Easterly stream of air (between the N. Ely, and S. Ely 'winds) extending over several degrees, and directed towards the vortex. '(*See* Fig. 22 p. 67) On that day, then, and on subsequent days, the 'bearing of the centre at some distance, could not have been determined 'by the rules laid down on the subject. From the winds and weather at 'Port Louis on the 25th, for example, the centre, according to the 'Law of Storms, should have been due North of the Island, whereas it 'was W.N.W. of it ; and the bearing of the centre from St. Denis, 'where the wind was S.E., should have been N.E., whereas it was about 'N.N.W.'

" In a description of another storm which occurred in March, 1860, we read as follows :—' Although the storm on some days appeared to be 'more circular than on others, yet it is probable that during the whole 'time the wind blew round the centre spirally.

" An account of the hurricane of the 29th January to the 7th February, 1863, contains the following remarks :—' But it is evident 'that at some distance from the centre the wind was not blowing in a 'circle. The probability is that it was blowing towards it spirally. At 'all events, it was impossible for the *John Barrow*, *William Carvill*, '*Louisa*, &c., to determine by the Law of Storms the bearing of the 'centre at noon, although the wind was increasing fast and the barometer 'falling. The winds and weather experienced by these vessels would, 'according to the 'Law,' place the centre to the N.E.-ward of them; 'whereas it was nearly due North of the *William Carvill*, and N.N.W. of 'the *John Barrow*. All of them, in short, had the S.E. trade; but it is 'difficult to know when the trade forms a part of the 'storm *circle*.' 'Capt. TILLMAN of the *Louisa*, who was well aware that a cyclone was '*somewhere* to the Northward, ran to the Westward, apparently under 'the impression that, with the wind at S.S.E. and S.E., he could cross 'the storm's track before the centre could reach him; but after running 'nearly 200 miles W. ½ S. he found the wind hauling to the East, which 'made him give up the idea of passing in front of the storm. The 'storm was a revolving one, but it was only towards its centre that the 'wind blew in a circular direction, the curvature increasing as the centre 'was approached.'

"A description of a severe hurricane which took place from the 8th to the 22nd May, 1863, contains the following remarks:—'Although, 'however, it is quite evident that the wind blew round the centre 'uninterruptedly, it does not appear that it did so in a circle. The disc 'of revolving air was a vortex, the Western side of which was circular, 'or nearly so, while on its Eastern side the wind blew more or less 'towards the centre, the Westerly winds curving sharply to Northerly 'and N.Ely winds, and the Easterly winds blowing towards the centre.'

"The years 1864-68 being remarkable for a comparative absence of hurricanes in the Southern Indian Ocean, we had not many opportunities of studying their forms, and the bearings of their centres with respect to the directions of the wind. But from what we already knew, it was thought proper to call attention to the subject in a paper which was read before the British Association in 1867. The following is a quotation from the published report of that paper:—'As the trade wind in front of 'a revolving storm often blows in strong gales with a falling barometer 'over many degrees in longitude, and the direction of the wind, especially 'at a distance, is far from being at right angles to the bearing of the 'centre, severe losses have occurred in consequence of vessels, having 'the wind at S.E., running to the West or N.W., with the view of crossing 'the storm's path, under the impression that the centre bore N.E. In 'place of bearing N.E., when the wind is from S.E., the centre may bear 'North or N.N.W., and if the storm be travelling to the S.W., as is 'often the case, a vessel steering Westward or N.W. may be running to 'her destruction. During a hurricane in February, 1860, for example, 'a number of vessels left the roadsteads of Réunion with the wind at 'S.E., and running to the N.W., got into the heart of the storm. Several 'of them were wrecked on the coast of Madagascar, others were never 'heard of, and of those that returned some had to be abandoned.'

"On approaching a cyclone on its Southern side, a vessel always encounters a strong trade wind, and the bearing of the centre can seldom be inferred from the direction of the wind. This is often exemplified at the commencement of a storm at Mauritius, as already referred to in the cases of the hurricanes of March 1818, and January 1860. But we are not now alluding to such cases, but to the direction of the wind in what may be called the body of the storm.

"At 8.30 a.m., on the 25th February, 1860, a number of vessels in the roadstead of St. Denis received orders to put to sea. The barometer was then at 29·68 inches; the sea was very high; the wind was blowing from S.E. in gusts; much rain was falling in the squalls; the nimbus clouds were moving with great rapidity; the sea was increasing more and more, and everything indicated the approach of a hurricane.—(Bridet, *Etude*, &c.)

"In all, 41 vessels left the roadsteads of Réunion, either on the morning of the 25th, or previously.

"Now, as the wind was from S.E., the 'Law of Storms' placed the centre away to N.E., and naturally enough the advice given to the commanders of these vessels would be to run to the N.W., so as to cross the storm's path, in front of the centre, and get into the N.W. quadrant. But we have ample proof that at noon on the 25th, the centre of the storm was nearly 150 miles N.N.W. of St. Denis, and that as it was travelling very slowly, the centre bore between N. by W. and N.N.W., instead of N.E., at the time the vessels put to sea from that roadstead, with the intention, no doubt, of crossing the storm's path.

"Most of the vessels steered towards some point between N.W. and West, but only four of them succeeded in crossing the storm's path in front of the centre. One of these was a steamer, and two of the other three had put to sea from other roadsteads before the 25th. Fortunately for them, the storm was travelling at the rate of only two to three miles an hour, otherwise they would probably have been less fortunate. If the storm had been progressing at the rate of five or six miles an hour, as often happens, they could not have crossed in time.

"Four other vessels which steered West, in place of N.W., escaped without serious loss. This is entirely attributed by M. Bridet to their having kept on the port tack, but their comparative safety was fully as much due to their having been considerably farther from the centre than the vessels which ran to the N.W.-ward. One of the commanders, on his return, thought fit to apologise to the Port Captain for not having followed his instructions. 'According to the Law of Storms I should 'have run to the N.W. to try and pass to its navigable side, but the 'fear of broaching-to prevented me, and I resigned myself to receive the 'full force of the hurricane, my ship, in fact, being quite prepared for 'lying-to.' It was well that he did not run to the N.W.

"As for the remaining 33 vessels, the results were deplorable: 55 men perished, either swallowed up by the sea, remarks M. Bridet, or succumbing to disease contracted after the sufferings of shipwreck. Three vessels disappeared and were never heard of. Three more were wrecked on the coast of Madagascar. Four were afterwards condemned at St. Denis, and two more at Port Louis. In fine, only 10 vessels sustained slight damage, the remaining 31, either through total loss, or necessary repairs, costing the insurers, according to M. Bridet, 3,360,000 francs, or £134,400.

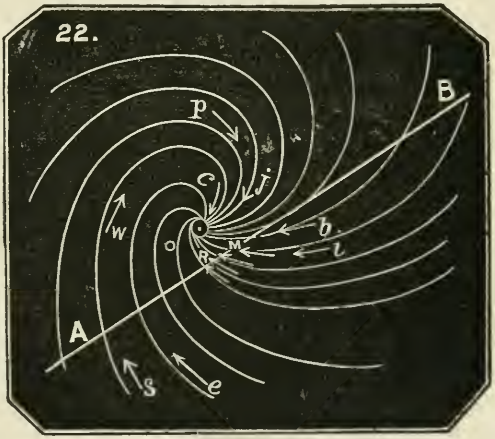
"While lamenting these disasters, M. Bridet, in very strong terms, ascribes them to the ignorance or the culpability said to have been shown by the commanders in not having acted in conformity with 'the principles of the new science.' But it will not, we think, be difficult to prove, that, on this occasion at least, the 'principles' themselves were more at fault than the commanders.

"When the wind was from S.E. at St. Denis (Réunion) on the morning of the 25th, with a rather low and falling barometer and every appearance of a hurricane, M. Bridet, believing that the centre of the cyclone bore N.E. and that the vessels were in front of it, would have no doubt counselled the commanders to run to the N.W. with all possible speed.

"Now, the centre did not bear N.E. but between N. by W. and N.N.W.

This very important point is fully proved by observations made at Mauritius (M), and Réunion (R), and by the following vessels:—*Emily Smith* (*e*), *Swallow* (*s*), steamer *Somme* (arrow above R), *Colbert* (arrow below R, or Réunion), *Ocean Wave* (*w*) near Foule Point, *Phœnix* (*p*), *Johanne* (*j*), *Chêne* (*c*), steamer *Bahiana* (*b*), and *Jemmy* (*i*).[*]

"We have, then, the direction of the wind at 12 different points on all sides of the centre: and these show that, at noon of February 25th, the centre was in latitude 18° 40′ S., longitude 54° 30′ E., near the position of the *Chêne*. These observations, however, not only enable us to determine with sufficient accuracy the position of the centre at noon on the 25th, but they also afford a good idea of the form of the cyclone (*see* Fig. 22.) We see that from the *Emily Smith* and *Swallow* northwards to the *Ocean Wave*, the wind curved round from S.E.-ward to S. by W. on the S.W. and West sides of the storm, but that as it pursued its course to the N.E.-ward it must have sharply curved so as to form the N.N.W. wind experienced by the *Phœnix*. It then gently curved round on the N.E. side of the



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[*] The letters show the positions of the vessels, and of Mauritius and Réunion on Fig. 22, between lat. 14° and 26° S., long. 45° to 63° E.

storm, as shown by the N.E.-ly. winds of the *Chêne* and *Johanne.* To the Southward and Eastward of these vessels, again, we find, as at Mauritius and with the *Bahiana*, an Easterly wind almost directed to the centre, while at and near Réunion there was a strong S.E.-ly. wind, also blowing more or less towards the centre.

"About 150 miles to the N.E. by N. of St. Denis the *Johanne* had a hard gale from N.N.E., whereas if the S.E. wind at St. Denis had belonged to a *circular* storm, the *Johanne* should have had the wind from N.W. by N.

"M. BRIDET does not give the position of the centre at noon on the 25th, but he places it at noon on the 26th in Lat. 19° 2′ S. Long. 53° 20′ E., and it was placed by us in Lat. 19° S. Long. 53° 30′ E., which is practically the same. But we have seen that at noon on the 25th, the centre was in 18° 40′ S. and 54° 30′ E. From noon on the 25th to noon on the 26th, therefore, the storm travelled nearly 62 miles on a W.S.W. course, or at the rate of 2·6 miles an hour.

(*See* Fig. 22 for the position of the centre on the 25th—towards which the spirals converge, and on 26th, indicated by a small white circle.)

"We thus arrive at the following important results :—

"Three hours after the vessels left St. Denis on the 25th, with the wind from S.E., the centre bore about 150 miles to the N.N.W., and as the storm was travelling at the rate of only 2·6 miles an hour, it is clear that at the time the vessels put to sea (9 A.M.) the centre must have still been nearly in the same direction, the storm in the three hours' interval having progressed only 7·8 miles to the W.S.W. At noon on the 26th, the centre was 160 miles due N.W. of St. Denis. Hence, if the vessels had all steered N.W. on leaving St. Denis, at the average rate of seven knots an hour, they would have reached the spot occupied by the centre at noon on the 26th (as given by M. BRIDET himself) at 8 A.M. on the 26th, or four hours sooner than the centre, and have been at a distance of only 10 miles from it.

"A part of M. BRIDET's censure is directed against those commanders, who, by running to the N.W., and getting ultimately involved in the dangerous part of the hurricane, did not from the outset run on the port tack. But what we contend for is, that as the centre did not bear N.E. but N.N.W., it was, under any circumstances, most dangerous to steer to the N.W., and that heavy losses were to be fully expected, seeing that the vessels were going straight to the centre. Four did succeed in crossing the storm's path in front of the centre. But this was the result of mere hazard, for it is certain that none of these vessels, when they left St Denis, knew either the bearing of the centre or the storm's rate of progression. They owed their safety to the fact that the storm was travelling very slowly, and probably to the circumstance that they were enabled to run faster than the other vessels, and very little merit is due to their commanders.

"Moreover, the vessels that were fortunate enough to cross in front of the storm kept on the starboard tack, which, as the storm was travelling on a W.S.W. course is the tack usually recommended to vessels about to pass into the right hand semicircle, it being expected that the S.E. and S.S.E. winds would soon veer to South and S.W. That the less fortunate vessels, therefore, should be blamed for running on the starboard tack at the outset, is, we think a mistake. For aught they knew, the storm might have been travelling on a S.W. by S. course, in which case they would have been at the outset in the right-hand semicircle. It is true that, when they found the wind hauling to the East, they should, if possible, have been put on the port tack. But this may have been impossible. They ran to the Northward, in expectation of the wind veering to South and S.W., and before the S.E. and S.S.E. wind began to veer, not to South, but to East, they were irretrievably involved in the storm. Their great misfortune was that they held to the N.W. at all, on any tack.

" We pass to another point which bears on the subject :—

" It has been observed at Mauritius that when cyclones pass on the North of the island, the wind often veers only from S.E-ward to N.E-ward, or to North at the utmost, although in pursuing its course, the centre of the storm is afterwards found to bear West or even S.W. of the Observatory.

" In the destructive hurricane of the 18th to the 29th February, 1860, for example, already referred to, the wind veered only from S.E. to N.N.E., and then gradually backed to E.S.E. ; and when the wind was from N.E. on the 27th, the centre of the storm did not bear N.W., according to the 'Law,' but West.

" Again, in the great hurricane of the 9th to the 19th February, 1861, the centre of which passed between Mauritius and Réunion, the wind, it is true, veered from S.S.E. to East, N.W., and West, but its direction was not a sure indication of the bearing of the centre. On the 17th, for instance, when the wind at Port Louis was from N.N.W., the centre did not bear W.S.W., but between S.S.W. and S. by W.

" From the 4th to the 10th January, 1871, a storm passed on the North of Mauritius. The wind at the Observatory veered only from S.S.E. to N.E., and then backed to E.S.E. The storm was traced from latitude 17° S., longitude 60° 45′ E. at noon on the 4th, to latitude 30° 28′ S., longitude 57° 48′ E. at noon on the 10th. It travelled at first on a W.S.W. course, and afterwards on a S.W., South, and S.E. course, passing a few miles to the Westward of Réunion on the 6th, where it committed considerable damage. Now at noon on the 6th, when the wind at Port Louis was strong from N.E., the centre, in place of bearing N.W., was 180 miles to the S.W., the wind at Port Louis blowing directly towards it. Many persons at Mauritius thought that as the wind did not veer beyond N.E., Réunion would be spared, but the arrival of vessels with full information showed, not only that Réunion had suffered, but that the storm had passed to the Westward and Southward of that island.

"At a meeting of this Society held on the 23rd March, 1871, the storm's course and extent were discussed, and particular attention again called to the fact that the bearing of the centre was far from being at right angles to the direction of the wind, especially at a distance from it; and it was also remarked that, as usual, some of the vessels that had put to sea from Réunion had not since been heard of, they having run to the N.W., when the wind was from S.E., and probably got into or near the centre.

"About this time, I had a conversation with the harbour master, Captain WALES, on the subject, and made a rough sketch of what I conceived to be the form of cyclones in these latitudes. Captain WALES at once perceived the practical bearing of the remarks submitted to him, and in a few days he drew up a paper '*On the Converging of the Wind in Cyclones*,' which was read before the Society (*see* pp. 60-62.)

"Between the 8th and 19th February, 1872, a very severe hurricane came down from the E.N.E., the centre passing about 70 miles North of Mauritius early on the morning of the 6th, and 40 to 50 miles N.W. of Réunion in the night of the 16th to the 17th. It did little harm at Mauritius, but the crops at Réunion suffered greatly, and several lives were lost. At the Observatory (Mauritius), the wind veered from S.S.E. to N.N.E., and then backed to E.S.E. The storm's path and extent were discussed in a paper read before the Society on the 28th March, 1872; and we know beyond all doubt that when, at noon on the 17th, the wind was blowing at Mauritius in strong breezes from N.E. by N., the centre of the storm bore about 240 miles W.S.W. of the Observatory. On this occasion, also, a number of vessels put to sea from Réunion, and some of them have never returned.

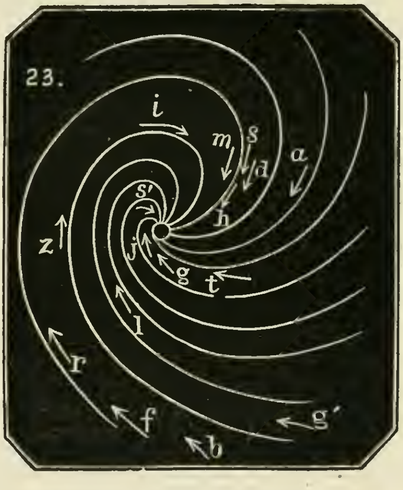
"From the 4th to the 10th January, 1873, another severe hurricane came from the N.E.-ward, passed North of Mauritius, and committed great damage at Réunion, blowing down buildings, destroying the crops, and causing general distress. We know that at Mauritius the wind veered only from S.E. to N. by E., remaining but a short time at the latter point, from which it backed to East, and that when the wind was from N. by E. the centre of the storm bore about S.W. by W.

"Shortly after the storm of 1871 or 1872 (I forget which), I received some copies of a Réunion newspaper containing a discussion of the storm by M. BRIDET, as well as several letters, in which the writers, or some of them, requested that gentleman to explain the fact that the wind at St. Denis did not veer more than it did, the circular theory requiring it to have passed to the West of North. I am not aware that M. BRIDET has given any satisfactory answer to these inquiries, his reply merely re-asserting the correctness of the 'Law of Storms' as expounded by himself and others. Another writer, however, has suggested that, in approaching Mauritius and Réunion, cyclones might be flattened in consequence of the resistance presented by the high lands of these islands, and, if so, that this would account for the wind veering so little. But an examination of storms which have taken place at a great distance from high land shows that their forms were nearly the same as in the case of storms passing near Mauritius and Réunion, and therefore the supposed influence of the mountains of these islands in altering the form of cyclones cannot be accepted as an explanation of the observed facts. This is a point of so much importance that we do not hesitate to give the details, for one day (the 16th), of the hurricane of the 8th to the 22nd May, 1863.

(The ships involved were the *Golconda* (*g′*), *Francis Banfield* (*b*), *Formosa* (*f*), *Rajasthan* (*r*), *Lochnagar* (*l*), *Fez Rabannee* (*z*), *James Russel* (*j*), *Glendevon* (*g*), *Tjielingsie* (*t*), *Suger* (*s′*), *Ibis* (*i*), *Alice Maud* (*m*), *Scinde* (*s*), *Earl Dalhousie* (*d*), *Herald*, (*h*), *Adela* (*a*) and the *Fairy*, represented on Fig. 23 by their respective letters: the area embraced is from latitude 0 to 26° S., and between longitude 71½° and 89° E.)

"The centre of the storm at noon was in latitude 11° 20′ S., longitude 78° 50′ E., or about 20 miles to the Eastward of the *James Russel*.

"The relative positions of the vessels, and the winds they had (as laid on down Fig. 23) show that the S.E. trade-wind gently curved round on the the West side of the storm, as shown by the logs of the *Golconda*, *Francis Banfield*, *Formosa*, *Rajasthan*, *Lochnagar*, and *Fez Rabannee;* that nearly 380 miles due North of the centre the *Ibis* had a strong breeze from West; that between the *Ibis* and the *Alice Maud* the wind must have curved sharply round from West to N.E.; that the N.E.-ly. winds of the *Alice Maud*, *Scinde*, *Earl Dalhousie*, *Herald*, and *Adela* were directed towards the centre; and that when the *Tjielingsie* had a storm from E.S.E. to East the centre bore about 120 miles to the N.W.-ward of her.


23.

"The form of this cyclone, therefore, strongly resembled that of the 25th February, 1860, which will be best seen by comparing Figs. 22 and 23.

"The *Earl Dalhousie* had been *scudding* since 5 P.M. on the 14th, and by 8 A.M. on the 16th she had gone *three* times round the centre, the wind veering regularly from N.E. to East, S.E., South, S.W., West, &c., back to N.E., until at last she apparently got into the central calm for a few minutes at 3.30 A.M. on the 16th. But no sooner did she get out of the centre, with the wind at N.N.W., than she again began to scud. By this time, however, the storm, which had been almost stationary, was travelling at the rate of 15 miles an hour, and she could not manage to run round the centre a fourth time. Still she held to the S.W. before the N.E. wind at the rate of 10 to 11 knots an hour, until, finding little improvement, she was hove-to at 6 P.M.

"During the latter part of the 16th and the earlier part of the 17th, the vessels that had the wind from the N.E.-ward (*Alice Maud*, *Scinde*, *Earl Dalhousie*, *Herald*, and *Adela*) were either hove-to, or proceeding slowly to the Southward or S.W.-ward. But on the 17th, the weather having much improved, and the barometer risen considerably, they ran to the Southward and S.W.-ward, and on the 18th, the storm recurving and travelling slowly, most of them got into the centre, or close to it, a second time, and suffered severely.

"The *Earl Dalhousie* scudded as before; but by the time she had brought the wind from N.E. to S. by W., the rudder head twisted, and refusing her starboard helm, the ship broached-to on the starboard tack, and went over on her beam ends, with her lower yards in the water, the lee main deck full, and the sea washing up half-way on the poop deck. In this dilemma, it was found necessary to cut away the three masts by the deck.

"The *Alice Maud* foundered, but fortunately her officers and crew were saved by the *Chanaral*.

"The *Herald*, proceeding more slowly to the S.W.-ward than the *Earl Dalhousie*, got into the centre only at 10 A.M. on the 19th, and was dismasted.

"At 10 P.M. on the 16th, the *James Russel* had the wind from W. by S., from which it veered to W.N.W. and North early on the 17th. The weather being now more moderate, she ran South with the wind veering to N.N.E. and increasing, and by 3 P.M. on the 18th, after being dismasted, she was in the central calm, with her barometer at 27·30. At 5 P.M., the wind recommenced from West to S.W., and blew with great fury for two hours.

"The *Scinde*, going at the rate of only 2 to 3 knots, did not get near the centre a second time, but the *Adela* came up close to it, and was in great danger of foundering.

"The *Fairy*, which had also the wind moderating at N.E. on the 16th (position not given), bore away S.W., and on the 17th she was 'running before the wind (from N.E.-ward) with all possible speed.' At noon the 18th, in latitude 14° 9′ S., longitude 78° 10′ E., with a furious hurricane from the N.E.-ward she was laid-to on the starboard tack. 'At 6 P.M, the 'hurricane, which was then raging with tremendous fury, ceased in less 'than one minute to an entire calm.' At 7, the hurricane recommenced from the opposite quarter, namely, S.W. She was then kept right before the wind, but in ten minutes she was thrown on her beam ends, and was for some time in great danger. On the 20th, she was abandoned, her officers and crew taking refuge on board the *Arundel* from Bombay to Liverpool.

"It is quite certain that all these vessels, if they had not run to the Southward and S.W.-ward, but had stood back for 48 hours, would have escaped. But what we have especially to remark is this, that, in all probability, the commanders were entirely mistaken as to the bearing of the centre. Most of them had been more or less involved in the hurricane from the 12th to the 16th, but at last the wind began to moderate, and the barometer to rise rapidly. Now, with the wind from N.E., and the barometer low, though rising, the centre, according to the circular theory, should bear N.W.; and, as the weather improved and the barometer continued to rise, it would naturally be inferred, that, with the centre in that direction, and its distance increasing, there could be no great danger in running to the S.W.-ward. But at noon on the 16th, when the wind was from N.E.-ward, the centre was from 200 to 300 miles to the S.W.-ward of the vessels, and, therefore, at that distance the wind blew directly towards it; and it cannot fail to be remarked that this is analogous to what has already been pointed out in the case of hurricanes passing near Mauritius and Reunion, the N.E.-ly. winds at a distance blowing more or less towards the centre.

"On the other hand, we have evidence that, near the centre, the wind blows, if not in a circle, at least nearly so. A good example of this is furnished by the *Earl Dalhousie* in running round the centre of the hurricane of May, 1863. At noon on the 15th, she was in Lat. 8° 55′ S., Long. 84° 32′ E. The following is an extract from her log:—

"'At 1 A.M. a heavy gale from East; course West, 10 to 11 knots. At 2, wind S.E.; course N.W., 10 to 11 knots; raining in torrents. At 3, wind South; course North, 10 knots; the roaring of the wind is something fearful, and the intense darkness is truly appalling. At 4, wind S.W.; course N.E. 10 knots; bar. 29·70. At 5, wind W.N.W.; course E.S.E., 10 to 11 knots. At 6, wind N.N.W.; course S.S.E., 10 knots. At 7, wind North; course South, 11 knots; blowing with tremendous fury, and raining in torrents; bar. 29·45. At 8, wind N.N.E.; course S.S.W., 11 knots. At 9, wind N.E. by E.; course S.W. by W., 11 knots. At 10, wind East; course West, 11 knots; bar. 29·35; same weather and sea; still scudding.'

"It would thus appear that it took 9 hours to go completely round the centre, and as the distance run was 95 miles, the diameter of the cyclone, on the supposition that the wind blew in a circle, and that the storm was stationary, would, with the *Earl Dalhousie*, be nearly 30 miles. The storm, however, was not stationary, but travelling at the rate of 3·3 miles an hour to the S.W.-ward. During the two hours, therefore, it took to bring the wind from East to South, the centre would have advanced nearly 7 miles, and have approached the vessel when on the S.W. side of the storm. But in getting round on the Northern and Eastern sides her distance from the centre would be increasing. This may partly account for the fact that in the Western half of the storm the wind veered rapidly, taking only about 3½ hours to pass from East to West, whereas it took 5½ hours to pass from West to East. There is reason to suppose, however, that even at that short distance from the centre, the wind on the N.E. and Eastern sides of the storm were incurving towards the centre, for it took only one hour to bring the wind from S.W. to W.N.W.

apparently showing the sharp curving in that part of the storm already alluded to, while it took a whole hour to bring the wind from W.N.W. to N.N.W.; and it will be seen that it remained 2 hours between North and N.E. by E., whereas on the Western side it veered four points in one hour. During all this time, the vessel was gradually approaching the centre, for with the N.E.-ly. and Easterly winds, she gained more than she had previously lost.

"Her next run round the centre was performed in a little more than 8 hours; and as the subject is rather interesting, it may be proper to give the log in full, commencing where we stopped with the wind at East:—

"'At 11 A.M., wind S.E. by E.; course N.W. by W., 11 knots; ship labouring very much. Noon, wind S. by E.; course N. by W., 10 to 11 knots; sky densely overcast; same fearful hurricane, and rain in torrents; bar. 29·25. At 1 P.M., wind S.W. by W.; course N.E. by E., 10 to 11 knots; dense upper clouds, and light lower scud flying in various directions. At 2, wind W.N.W.; course E.N.E., 10 to 11 knots. At 3, wind N.W. by W.; course S.E. by S., 10 knots; blowing a most severe storm with constant heavy rain. At 4, wind North; course South, 11 knots; bar. 29·20. At 5, wind N.E.; course S.W., 11 knots. At 6, wind E. by N.; course W. by S., 12 knots. At 7, wind E. by S.; course W. by N., 12 knots.'

"From 10 A.M. to about 6½ P.M. the wind veered right round the compass, the vessel making 92 miles; and it will be seen that, as before, the wind must have curved sharply from S.W. by W. to W.N.W. and very slowly from W.N.W. to N.W. by N.

"It would be easy to adduce many more instances showing that at least at some distance from the centre the form of cyclones in the Southern Indian Ocean is not truly represented by concentric circles, and that the rule usually given for ascertaining the bearing of the centre is often inapplicable. But we must stop here for the present, and now proceed to state briefly the conclusions at which we have arrived.

"To find the exact directions in which the wind blows in a hurricane is not an easy matter. The true positions of the vessels are not always given, especially when their courses are frequently changed, and it is impossible to get observations of the sun or stars. It doubtless happens, also that the directions of the wind as given in the log books are often incorrect to the extent, it may be, of two or three points. Then, although it may be quite certain that a cyclone exists, yet there may be only two or three vessels involved in it, and these may be all in the same part of the storm. For these reasons, it takes a long time, and an investigation of many cyclones, to obtain an approximate knowledge of of their forms. We, in fact, get only occasional glimpses, at such times as, in consequence of many vessels being on all sides of a storm, we can obtain good averages; and this will account for the want of precision which sometimes characterises the allusions made to the forms of cyclones in the descriptions which we have given of them.

"Comparing, however, the results obtained during the last 20 years, and especially the last 12 years, we have no hesitation in saying, that, generally (we do not say always), fully developed cyclones in the Southern Indian Ocean have the same form as the cyclones of the 25th February, 1860, and the 16th May, 1863.

"The forms of these two cyclones are given in Figs. 22 and 23, as examples of what may generally be expected.

"It will be seen, as already remarked, that the S.E. trade-wind curves round on the Western side, giving the storm in that part of it a more or less circular appearance, but that the wind curves sharply from West to N.W. and North, and that the Easterly winds (particularly from E.N.E. to E.S.E.) blow nearly towards the centre, except when near it.

"The line A B (Fig. 22, p. 67) is supposed to pass through Mauritius, and it will be seen that the storm commences with the wind from S.E.-ward at A, but that as the centre advances to the S.W.-ward the wind gradually veers to North at B.

"The extent to which the wind veers at a fixed point must depend upon the size of the storm, the distance from the centre, and the diameter of the more circular part near the centre.

"Having given the general form of cyclones, I should perhaps leave the rest to practical men. But there can be no harm in stating, subject to correction, what appears to be necessary for avoiding the centre; and in doing so I will quote here some remarks made in April, 1863:—

"'A rotatory storm, in the Indian Ocean, not being a detached body of air whirling round in a circle—beyond which light airs and variables prevail—but the result of the conflicting action of two antagonistic winds which often respectively extend hundreds of miles North and South of the centre, towards which they at a distance begin to curve gradually, the degree of curvature increasing as the centre is approached, until at length they rush round it with more or less violence, it becomes a question of practical importance to know *when* can the direction of the wind be relied upon for a sufficiently near estimate of the bearing of the centre; for by considering the direction of the wind, when it is S.E., for example, to be *tangential to a storm-circle*, and then running to the Westward, with the view of crossing the storm's track, the vessel may be steered headlong to destruction.

"'There does not appear to be much difficulty in avoiding a rotatory storm when the vessel is in its Northern half, and has the wind at any point from South to North, *through the West*, or even from South to N.E. through the West.

"'If the wind be between South and West, a vessel should run to the N.W.-ward.; if it be between West and North she should run to the N.E.-ward.; and if it be from N.E.-ward, she should make as much Easting as possible.

"'Or, if the sea and weather allowed, she might be hove-to on the proper tack till the barometer rose and the weather improved, *except*, perhaps, when the wind is from N.E., in which case, if she be between the parallels of 18° and 30° S., the storm *may* be travelling to the S.E.-ward, and bearing down upon her. If such should be its course, she should endeavour to cross its path by running to the S.W.-ward.

N.B.—Compare this exception with paragraph (6) p. 78, where Mr. MELDRUM, as the result of 10 years' additional experience, advises "making as much Easting as possible," instead of running to S.W.-ward.

"'When, however, the wind is from any point from South to North, by the West, there is really no danger whatever. All that is required is either to stand away from the centre, by going to the Westward, the N.W.-ward., the Northward, the N.E.-ward., or the Eastward, according to the direction of the wind, or to lie-to. It might easily be shown that *all* the homeward bound vessels that come here for repairs, in consequence of their having sustained damage in a cyclone, which they entered *from* the North, incurred the heavy expense and the long delay thus occasioned, by running to the Southward or S.W.-ward., in place of heaving-to in time, or standing off till the barometer should rise and the weather improve. There is a strong temptation to such vessels to hold their course with a *favourable* breeze; but an increasing Northerly or N.E.-ly. wind, with a falling barometer and bad appearance, should warn them of the extreme danger of running to the S.W.-wards at the rate of perhaps 9 knots an hour. How many vessels, by taking supposed advantage of these Northerly winds, have got in front of a storm, been dismasted, and afterwards obliged to remain at Mauritius for months, if they should escape being condemned! A delay of 24 or 48 hours would, almost in every instance, have saved both vessel and cargo.

"'On the other hand, to vessels with the wind between South and East, or E.N.E., especially between S.S.E., and East, the case is widely different; for the storm is travelling *towards some* point between W.S.W. and S.E., and that point cannot always be known, because the wind may not, as yet, be blowing round the centre of the storm in a circle, although the barometer be falling and the wind increasing.

"'To vessels in this situation the safest course seems to be to lie-to, and carefully watch the wind and barometer.

"'If the wind should haul decidedly, either to the East or to the South, the passage of the centre, with respect to the vessel's position, may be approximately inferred.

"'When the barometer has fallen four-tenths of an inch, the direction of the wind may be taken to be nearly at right angles to the direction of the centre.

N.B.—After 10 years' more experience, a fall of *SIX*-tenths is considered necessary before the above conclusion can be drawn; *see* paragraph (5) p. 77.

"'If the vessel should then have the wind from S.E., she should endeavour to run to the Westward, so as to cross the storm's path. By running to the Westward before the barometer has fallen more than a tenth or so, she may be approaching the centre of the storm, as the *Louisa* was doing when she had the wind from the S.E.-ward on the 2nd February, 1863.

" 'With the wind from S.E.-ward, the same difficulty presents itself to vessels at anchor at the *bell-buoy* (Mauritius) and at Réunion, namely, that of knowing the bearing of the centre, as, at the outset, the wind may be far from blowing at right angles to the direction of the centre. If the centre should bear North or N.N.W., in place of N.E., and the vessel run to the N.W.-ward, she may, by keeping that course, get into the heart of the storm, as has frequently happened to vessels leaving St. Denis, and as probably happened to the *Shah Allum*, after she left the *bell-buoy* in January, 1863.'

" 'The best course would perhaps be (if the vessels cannot be brought into port) to put to sea on the *first* decisive indications of the coming storm, and, after obtaining sufficient sea-room, to lie-to, watch the wind and barometer, and be guided by them ; not hesitating to run to the Westward or N.W.-ward., if the barometer should have fallen three or four-tenths of an inch, with the wind between S.E. and South ; but, if the wind should haul from S.E. to East and N.E., taking care that the vessel be hove-to on the port tack, after getting as far to the Eastward as possible.'

" After ten years' further experience, we have little to add to what was said in 1863.

"(1.) The really dangerous position for a vessel is with the wind from N.E.-ward to S.S.E., and more especially from the S.E.-ward.

"(2.) When the wind is between N.E. and E.S.E., our advice would be to lie-to at once.

"(3.) With the wind from S.E.-ward, and the barometer still high, though falling, we would also heave-to, because, as yet, the bearing of the centre cannot be known. If the wind hauled decidedly to the Southward, and passed to the South of S.S.E., we would stand to the N.W.-ward without loss of time, but if it veered to the Eastward we would either lie-to on the port tack, or endeavour to make Easting.

"(4.) On no account whatever would we run to the Southward or S.W.-ward with the wind anywhere between North and East, but make as much Easting as possible.

"(5.) The most dangerous case of all is when the wind is steady from S.E., the barometer falling, and the wind gradually increasing in force. What is a vessel to do under these circumstances?—If she runs to the N.W. she may be going straight to the centre. Upon the whole, we think she cannot do better than lie-to and watch the wind and barometer. The chances are that the wind will veer, and that she will know, before it is too late, whether it is best to run to the N.W.-ward, or remain where she is, or hold to the Eastward. But if the wind does not veer, and the barometer has fallen from the commencement fully *six*-tenths of an inch, we would, as a last resort, run to the N.W.-ward if possible. We say *SIX*-tenths *because four-tenths* which was the amount of fall mentioned in 1863, *is too small.* (In the centre of a cyclone in these seas, the barometer always falls below 28 inches.)

"The above remarks apply chiefly to vessels encountering cyclones which have not yet commenced to curve to the Southward and S.E.-ward.

"(6.) When a storm is travelling to the Southward or S.E.-ward, I would still, with the wind anywhere between North and East, make as much Easting as possible, *and not*, as recommended in 1863, *run to the S.W.-ward.*, for we now know the N.E.-ly and Easterly winds often, if not always, blow towards the centre.

"(7.) Storms do not always curve to the Southward and S.E.-ward, and those that do so seldom proceed far in those directions. But if it was found that a storm was travelling to South or S.E., a vessel with the wind from E.S.E. to South should hold to the Westward.

"It may be proper to remark that the modifications above mentioned, as to the form of cyclones, do not very materially affect the general theory of revolving storms, as established by REDFIELD and REID in America and the West Indies, and by PIDDINGTON and THOM in Calcutta and Mauritius, although, I think, they deserve the attention of all interested in navigation. They are, in some measure, a compromise between Prof. ESPY'S views and those of the advocates of the circular theory.

"The forms given in Fig. 22, p. 67, and Fig. 23, p. 71, apply to storms when fully developed, and before they begin to break up. These storms are usually generated between an Easterly and Westerly current of air, and cease between a Northerly and Southerly current, so that at their commencement they are flattened on their Northern and Southern sides, and towards their close on their Western and Eastern sides."

Such are the conclusions at which Mr. MELDRUM has arrived as to the *form* of cyclones in the southern hemisphere. But no less important, and much to the same effect, are the results of later observations made in the Bay of Bengal, as shown by the Official Reports of Prof. W. G. WILLSON, of the Meteorological Department of the Bengal Government, on the cyclone of June 1872, known as the Balasore cyclone, and on that of October 1874, which swept over the Midnapore and Burdwan districts. It is from the former of the two reports that the following extracts are chiefly made:—

The Balasore cyclone, so called from the name of the place where it struck the land "was not one of great violence, and was unusually small in dimensions, its radius, probably, never exceeding forty or fifty miles; the vortex, it is calculated was formed on the night of June the 29th, or the morning of June the 30th, at or about Lat. 19° 50′ N. and Long. 89° E. For some time after its formation, it seems to have been almost stationary. It moved afterwards with a velocity of about ten miles an hour, as it passed the Pilot Ridge, between 8 P.M. and midnight of the 30th. It advanced in a northerly direction very slowly from midnight, retarded by friction with the land, turning round to the westward along a path with less resistance, with probably a smaller radius. It increased in extent and velocity of propagation, as it moved over a freer course towards Balasore.

"The following table shows the approximate track of the centre:—

June 30, 10 P.M.	20° 40′ N.	87° 55′ E.
Midnight	20° 55′ ,,	87° 50′ ,,
July 1, 3 A.M.	21° 8′ ,,	87° 45′ ,,
8.30 A.M.	21° 9′ ,,	87° 10′ ,,
11 A.M.	21° 7′ ,,	86° 45′ ,,

"It is probable that, previous to the formation of this vortex, another distinct vortex had been formed on the 28th, in about the same place—viz., Lat. 19° 50′ N., Long. 89° E.—but it appears to have been almost stationary, and to have broken up on the morning of the 29th."

The cyclone did not travel over much more than 300 miles, but observations made on the land, at Akyab, Chittagong, Calcutta, Saugor Island, and Madras, together with reports derived from no less than 26 vessels (including the lightships), give a very good account of, and are very conclusive in respect to, the wind and weather all round the coast and on the bay for many days. With all the vessels the gusts of winds are described as something fearful, and all agree in their description of the height and force of the waves; indeed, the tremendous cross sea, "which is reported never to have been equalled in the bay," was the speciality of this cyclone.

One vessel, the *Sophia Joakim*, appears to have been in a difficult and dangerous position on the 29th, with a lee shore to the north and the cyclone to the south; afraid to heave-to, she had to make a fair wind of it. On this circumstance, Mr. WILLSON observes that "running round a cyclone is always dangerous, more especially in those of small radius, and it is liable to be forgotten that the *winds do not revolve round the vortex in circles, but along in-moving spirals, so that a course before the wind must inevitably bring a ship sooner or later to the centre.*"

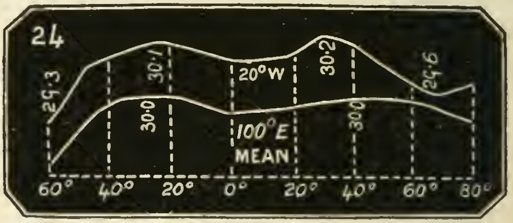
Again, "I wish to draw particular attention to the following *modern development of the laws of cyclonic storms*, for the disregard of this law may lead, and has led, to many losses at sea. 'The direction of the wind, especially at a distance, is far from being at right angles to the bearing of the centre. The wind does not revolve round the vortex in circles, but along incurving spirals, differing two, three or more points from the tangential circular directions.' Hence a ship, when running up the bay with a S.W. gale, squalls, torrents of rain, a barometer falling rapidly, and every appearance of a cyclone, has no right to conclude that the centre bears N.W., and that therefore a North or N.N.E. course is a safe one. The centre, if at a distance, may bear North or N.N.E., and a northerly course may run the ship into it, particularly as it may be then almost stationary. 'The safest course seems to be to lie-to, and watch the barometer and wind, till the bearing of the centre be known with some certainty.'

"It must be borne in mind that, before any vortex is formed, gales blow towards, and round a considerable belt of low pressure. In determining the changes of position of the centre of a cyclone from the veering of the wind, it must be borne in mind that the direction of the currents is not round a circle, but in a spiral, differing about two points or more from the circular direction, although close to the centre, the direction is probably more nearly circular. I use the following rule for the Northern Hemisphere :—‘ To find the bearing of the centre, *stand with your face to the wind, and measure round to your right hand side, about ten points* (*not eight*). When the centre is at a distance, it may bear eleven, twelve, or thirteen points from the direction in which the wind is blowing. *For the Southern Hemisphere the ten points would be measured round to the left !*’

“ When a ship cannot get out of a cyclone, and is obliged to lie-to, the well-known rule is :—‘ When in the right hand semicircle, heave-to on the *starboard tack*, and when in the left hand semicircle, heave-to on the *port tack, in both hemispheres.*’ A ship heaving-to on the wrong tack in a cyclone must drift into the centre, as it passes, and be taken aback by the veering of the wind.”

The Law of Storms now enters on a new phase, to appreciate which it will be necessary to briefly explain certain barometric phenomena intimately connected with atmospheric circulation.

The navigator who, day by day, or at shorter intervals, records atmospheric pressure, as indicated by the barometer, in a graphic form, understands that such a projection represents (according to his limited observations, and hence imperfectly) a *barometric curve* for the route he has traversed. If, after a somewhat similar method, but from more exact and continuous observations made at many different places, barometric curves be drawn to show the *mean annual* pressure of the atmosphere over certain parts of the globe, as, for example along meridional lines between Lat. 80° N. and 60° S., it will be found that however much these curves vary in curvature over different meridians they are characteristically alike in this—that there are two parts indicative of a higher pressure than elsewhere, so that on viewing them transversely to the meridian, *i. e.* in the direction of the parallels of latitude, they would present the atmosphere which encircles the globe as apportioned into five distinct bands or areas, viz., two of high pressure and three of low pressure.



(*See* Fig. 24 above, in which the upper curve represents (roughly) the atmospheric pressure over the meridian of 20° W., and the lower curve the atmospheric pressure over the meridian of 100° E.)

To Mr. A. BUCHAN (in 1868) is due the credit of having been the first to approximately solve the physical problem of the distribution of atmospheric pressure, and his views have since been corroborated by WOJEIKOF and others. In respect to the *mean annual* pressure, Mr. Buchan deduces the following important general conclusions:—

"There are two regions of high pressure—the one north and the other south of the equator—passing completely round the globe as broad belts of high pressure. They enclose between them the low pressure of the tropics, through the centre of which runs a narrower belt of still lower pressure, towards which the trade-winds blow. Since these belts of high pressure can only be maintained by air flowing in upon them in the upper regions of the atmosphere, it is towards these belts of high pressure that the upper currents of the air must flow. The southern belt of high pressure lies nearly parallel to the equator, and is of nearly uniform breadth throughout; but the belt north of the equator has a very irregular outline, and great differences in its breadth and in its inclination to the equator,—these irregularities being due to the unequal distribution of land and water in the Northern Hemisphere. Considered in a broad sense, there are only three regions of low pressure—one round each pole, bounded by, or contained within, the belts of high pressure just described, and the equatorial belt of low pressure. The most remarkable of these, in so far as known, is the region of low pressure surrounding the South Pole, which appears to remain pretty constant during the whole year. The depression round the North Pole is divided into two distinct centres, at each of which there is a diminution of pressure greatly lower than the average north polar depressions. These two centres lie in the north of the Atlantic and Pacific Oceans respectively."

These belts following the course of the sun, change their form and position, month by month, more or less rapidly according to the relative distribution of land and water. They have more uniformity in April and October, when atmospheric pressure appears to be more uniformly distributed over the globe, than during the other months of the year, while in January and July, the representative months of extreme seasons, occurs the greatest deviation from the annual mean.

Of the latter months Mr. BUCHAN remarks:—

"*In January* the highest pressures are over the continents of the Northern Hemisphere, and the larger the continental mass the greater the pressure; the lowest pressures are distributed over the northern parts of the Atlantic and Pacific, South America and South Africa, and the Antarctic Ocean. In Central Asia the mean pressure of the atmosphere in this month is fully 30·40 inches, whereas in the North Atlantic, round Iceland, it is only 29·34 inches, or upwards of an inch lower than in Central Asia. This area of high barometer is continued westward through Central and Southern Europe, the North Atlantic between lat. 5° and 45° N., North America (except the north and north-west part), and the Pacific for some distance on either side of lat. 15° N.:

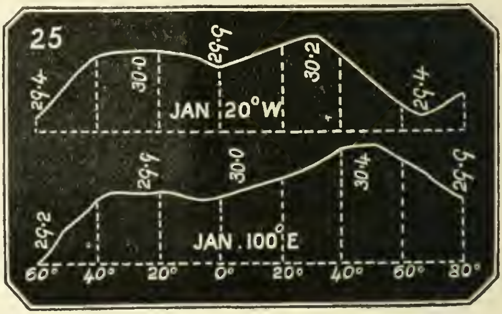
it is thus an exaggerated form of the high belt of annual mean pressure, —spreading, however, over a much greater breadth in North America, and a still greater breadth in Asia.

"*In July*, on the other hand, the mean pressure of Central Asia is only 29·47 inches, or nearly an inch lower than during January; or, putting this striking result in other words, about a thirtieth of the pressure of the atmosphere is removed from this region during the hottest months of the year, as compared with the winter season. The lowest pressures of the Northern Hemisphere are now distributed over the continents, and the larger the continental mass the greater is the depression. At the same time, the highest pressures are over the ocean, between lat. 50° N. and 50° S., particularly over the North Atlantic and North Pacific, between lat. 25° and 40° N.; and in the Southern Hemisphere, over the belt of high mean annual pressure, which in this month reaches its maximum. Pressure is high in South America and in Australia, just as in the winter of the Northern Hemisphere pressure is high over the continents."

The distribution of atmospheric pressure at different seasons is best elucidated by maps of the earth's surface on which the various belts of pressure are delineated in two different colours, as in BUCHAN'S "Introductory Text Book of Meteorology," or WOJEIKOF'S "Atmosphärische Circulation," to which the reader is referred for a fuller exposition of the subject. For the present it is deemed sufficient to project the substance of the foregoing remarks into curves.

A *mean* or *average* value is often but an inadequate expression for extreme differences, and this is especially the case in respect to meteorological phenomena, as may be seen by a comparison of the curves of atmospheric pressure in Figs. 24 (p. 80), 25 and 26, which are given (in each) for the same meridians, viz., 20° W. and 100° E.

The meridian of 20° W. passes along the length of the Atlantic, and wholly over water, with the exception of Iceland; comparing the January curve of pressure (Fig. 25) with that of July (Fig. 26), there is a difference between them which is *most* marked in the vicinity of Iceland, lat 62° N., but which is also sufficiently characteristic in the equatorial regions, where the belt of calms (or area of low pressure), towards which the trade-winds blow, shifts its position through several degrees of latitude, and the area of *lowest* pressure from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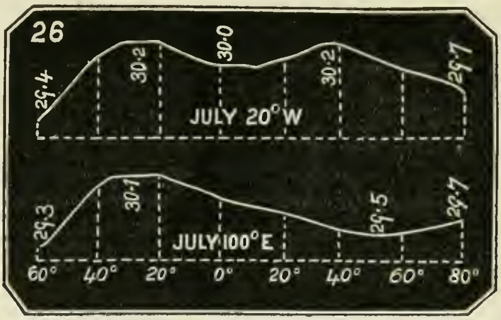
lat. 2° or 3° N. in January to lat. 11° N in July; and where also the parts of the curve which represent the belts of high pressure (in lat. 25° to 30°) on the polar sides of the trades show the greatest change in the Southern Hemisphere. The excessive low pressure of January, with its concomitant storms, in the vicinity of Iceland, disappears in July, while in the region of the great Southern Ocean the pressure remains comparatively unaltered, and always abnormally low.



The meridian of 100° E. mainly passes over land (Central Asia) in the Northern Hemisphere; but over the ocean south of the equator; hence the two seasonal (January and July) curves of pressure are markedly contrasted, nor do they bear the slightest resemblance to the curves which pass over the oceanic meridian of 20° W.; they, in fact, illustrate the effect of the irregular and unequal distribution of land and water, and show the difference which characterizes areas of pressure as principally influenced through one or the other element; thus, it is the northern portion of the curve which undergoes the greatest change: in January, from the high pressure region of Central Asia the N.E. monsoon blows towards the low pressure area, in lat. 5° S.; in July a reversion occurs, and from the vicinity of the equator the S.W. monsoon blows towards the same region of Central Asia, which is now one of remarkably low, as it had previously been one of remarkably high, pressure.—(*See* Figs. 25 and 26).

Exactly as the inter-tropical winds—the perennial trades and the periodical monsoons—are connected with and influenced by belts of high and low pressure, so are the *prevailing* winds, and hence the climate of every part of the globe. With the march of the sun from one side of the equator to the other, these belts (and with them the whole atmosphere) make annually one general oscillation — northwards in the northern spring, southwards in the northern autumn—not in one uninterrupted movement, but by a series of minor vibrations, until they have reached their most northern or southern limit, when the oscillations recur in the opposite direction.

The purpose has here been to indicate in a general way the geographical distribution of the belts or areas of high and low pressure,—not to enquire into their cause—whether they originate from temperature and humidity, or from these and other motive forces, the relation of which is at present little understood, for as Prof. H. Mohn says, "the chief problem in meteorology is the law of the variation of atmospheric pressure, and we may consider ourselves only on the threshold of a knowledge of it."* As a matter of fact the general atmospheric circulation is intimately connected with, if not entirely dependent on, these areas ; and as, on a large scale, the prevalent winds and general climate of tropical, extra-tropical and polar regions are more or less due to them, so, on a smaller one, *all* fluctuations of wind and weather have their origin in local and temporary variations of pressure.

And how does the general circulation take place ? An area of high pressure indicates a superfluity of air ; an area of low pressure a deficiency of air ; wind, which is simply air in motion, in flowing away from the area of high pressure circles round it with the sun, and towards and around the area of low pressure against the sun, in each hemisphere. The Trades, the Monsoons, the S.W. winds of Northern regions, and the "brave" N.W. winds of the Great Southern Ocean, all speak to the same effect ; and so, in a similar manner, wherever there is a local and temporary disturbance of the atmosphere, whether resulting in a high barometer, or in a low barometer as in a cyclone, the system of circulation is universal ; and, being so, it is on this that BUYS BALLOT has based the "Law of the Winds" which goes by his name, viz., the wind always flows from the region of the higher to that of the lower pressure, veering, in consequence of the earth's rotation, to the right in the northern hemisphere, and to the left in the southern hemisphere.

Dismissing this law for the present, and turning from areas of pressure which influence the general atmospheric circulation to those which, though they appear to have but a local origin and temporary existence, yet not unfrequently take a wide geographical range, as is the case with storms, and especially those of the tropics,—it may be premised that in this connection, as an area of *low pressure* has been called a *cyclone*, so an area of *high pressure* has been termed an *anti-cyclone*, owing to the reversal of the order of the circling winds.

Areas of Low Pressure, or Cyclones.—In the *northern hemisphere* (*see* Fig. 27) the wind circles round the central area of lowest pressure in a direction *against the sun*, or contrary to that of the motion of the hands of a watch. In the *southern hemisphere*, (*see* Fig. 28) the wind circles round the centre of lowest depression in a direction also *against the sun* (astronomically considered), but this motion is *there* similar to that of the hands of a watch. But so far as observation goes—shown by an examination of the weather maps of the northern hemisphere, and indicated by the reports of Mr. Meldrum at Mauritius, and those of Mr. Willson at Calcutta—this circling takes the form of a *spiral*,—the tendency of the wind being *inwards*, and towards the place of lowest barometer, at an angle which Mr. Clement Ley estimates to be about 69°, but which Mr. Buchan concludes to be generally from 60° to 80°, though sometimes as small as 45°, and on rare and peculiar occasions as much as 80° to 90°: thus the *direction* of the wind is intermediate between that of the commonly accepted theory of rotatory gales—winds blowing in circles returning on themselves—and the directly in-blowing theory of Espy, but more nearly approximating to the former than the latter—the inclination being rather centrifugal than centripetal.

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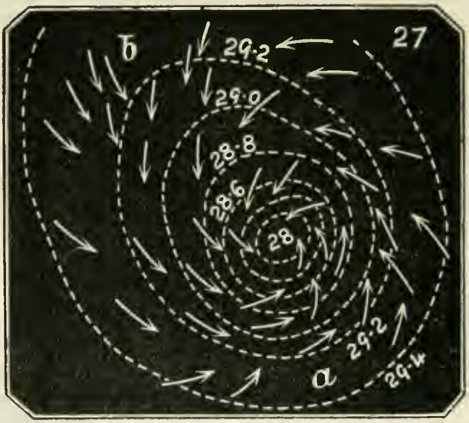
* As to the question of the origin of these areas of high and low pressure, respecting which there is some controversy, it may be well to quote an observation of DOVE's.—"Whenever two phenomena constantly occur together, we may, with some probability, presume that one depends on the other in the relation of cause and effect. But it will remain to be decided which of the two is the cause and which the effect, because it is not impossible that both phenomena may be the result of a third phenomenon ; nor, in fact, can it be at once decided whether, when one of the phenomena is really the immediate effect of the other, the same result may not be brought about in a different way."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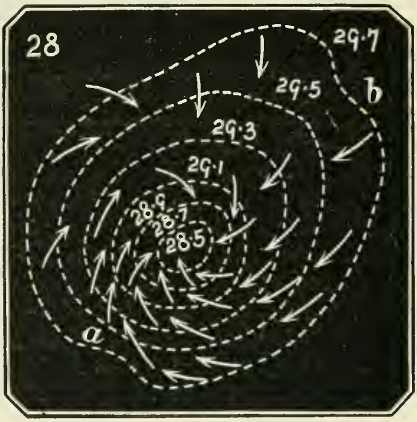
The *force* of the wind in a cyclone—in fact in all storms, and whenever wind blows around an area of low pressure—varies in different parts according to the amount of difference in the pressure over a given distance which is called the *barometric gradient.* Now, an *isobar* is the line (curved, circular or irregular) which passes through all places that at any given time have the barometer at the same height, thus, in Fig. 28 the outer irregular curve indicates in every part of it a barometric pressure of 29·7 inches, the next (inwards) a pressure of 29·5 inches, and so on. Regions of both high and low pressure are surrounded by such isobars *i.e.* by lines of equal barometric height. An area of low pressure has them crowded together,—generally more crowded on one side than on the other; and the wind will be strong in proportion as the isobars are nearer, or in other words, to the steepness of the barometric gradient.*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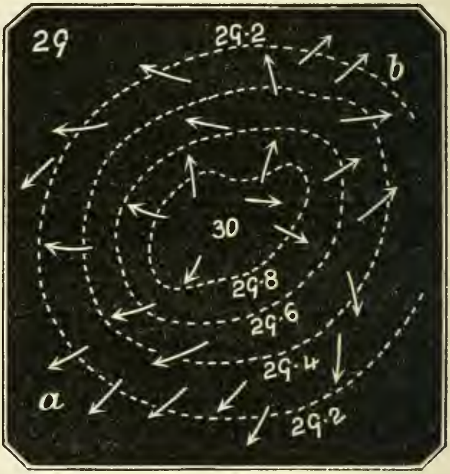
* The velocity or strength of the wind greatly depends on the difference of the barometrical readings over a given distance; if, with three places x y z, each successively 50 miles apart, the difference of readings is greater between y and z, than between x and y, it will blow stronger between the former (y z) than the latter (x y): if there is no difference in the barometrical readings there will be no wind.

Thus in Figs. 27 and 28, at the parts of the diagrams marked *a*, where the isobars close on each other, the wind will be stronger than at *b*.

Connecting these diagrams with the hurricanes or cyclones of the tropics ; it will be seen that the direction of the wind at any part will much depend on the shape or form of the area of low pressure ; and the strength of the wind upon the distance separating successive isobars.

Areas of High Pressure, or Anti-cyclones.—Wherever there is an area of low pressure there must be in the vicinity (so to speak) one or more areas of high pressure,—over which the isobars are more widely separated than is the case with those appertaining to cyclonic areas, and generally with greater irregularity of form ;—the winds are light, the weather fine, and the sky clear, especially at the centre. From the centre of highest pressure the winds stream outwards (*see* Fig. 29), often nearly at right angles to the isobars, but, as they pursue their course, they turn in an opposite direction to that assumed by the winds blowing inwards upon an area of low pressure—hence, with watch hands in the northern hemisphere, and against watch hands in the southern hemisphere. These are anti-cyclones in contradistinction to cyclones, and their meteorological difference is exceedingly well marked ; not only do they differ as regards the direction and circling of the winds, but the temperature and humidity of the winds connected with each have perceptibly distinct characteristics ; together, they are the concomitant agents in all atmospheric disturbances ; but it does not follow that every cyclone, considered from a meteorological stand-point, is a hurricane.



As these areas of maximum and minimum pressure are connected together at the surface of the earth by horizontally-flowing currents of air, and since the outflow from the anti-cyclone must be replenished and the inflow to the cyclone must be carried away, it is the most accepted view that the air ascends over areas of barometrical depression (cyclone) ; and descends over areas of barometrical elevation (anti-cyclones) ; from which it is farther inferred that in the upper regions of the atmosphere the conditions of pressure must be reversed as compared with those below ; in other words, over an area of low pressure there must be an excess of pressure at a certain level, causing an outflow of the air which is rising; and conversely over an anti-cyclonic area there must be a deficiency of pressure at a certain height, the tendency of which is to attract the air towards the region of its existence.*

It must be borne in mind that what has here been said of areas of high and low pressure, and their geographical distribution, has incidentally been introduced to explain to the seaman and general reader, in as brief a manner as possible, the connection of such areas with storms—not to discuss a subject that is now engaging the attention of the best meteorologists of Europe and America; the writer is conscious that the remarks, with the accompanying diagrams, can give but the rudest outline of an all-important branch of meteorology.†

Within the last few years meteorology has been studied on a sounder and more philosophical basis than formerly; and, in that department of the science bearing especially on temperature, moisture and pressure, together with the winds, research, or in other words systematized investigation founded on carefully recorded observations, has taken the place of pure conjecture based on imperfect data; much has been learnt but much more remains unknown; discussion and controversy are especially rife on the continent, where the constant topics are—hygrometric questions—causes of barometrical depressions—the barometer and real pressure of the air—relation between pressure and velocity of wind—relation of the velocity of the wind to the gradients—the effect of rainfall on the barometric pressure—the distribution of temperature in an ascending current of air—the origin and theory of storms—in fact whatever tends to improve our knowledge of the physics of the atmospheric with its vapour,—together with the mechanical effects of ascending, descending and horizontally-flowing currents of air, on which depends the theory of all atmospheric circulation. There can, however, be no question that a more systematic enquiry into the character of tropical storms is at present a great desideratum; for as yet, excepting the observations of MELDRUM, BLANFORD, and WILLSON, whatever is known of the cyclone, as a hurricane, has been derived from extra-tropical, and principally high northern, sources; but that knowledge, so far as it goes, does not lead to any other inference than that the cyclonic storms of all regions are very much alike—though it seems not improbable that those of the tropics may within a limited area be more persistently severe and destructive. It is hoped that, in the interest of navigation, our Meteorological Office may shortly be able to throw new light on this important subject.

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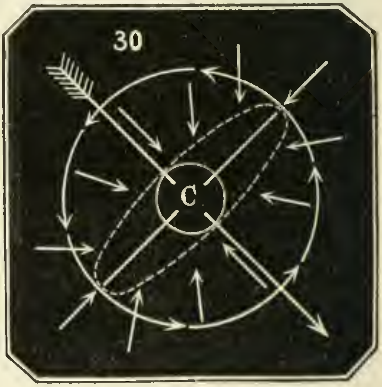
* Besides BUCHAN, WOJEIKOF, MOHN, and others, who agree on this point, Prof. HILDEBRANDSSON, from observations of the *cirrus* cloud, shows that air flows, away from centres of minima, and towards centres of maxima, in the upper regions of the atmosphere.

† At the last annual meeting (1876) of the Meteorological Society, Dr. Mann, the President, in his address compared the meteorological doctrine of high and low pressure areas of the atmosphere, and of the movement of currents of the air under the influence of the barometric gradient, to the Newtonian doctrine of gravitation in astronomical physics, to the Daltonian hypothesis of atomic proportions in chymistry, to the dynamic theory of the tides, and to Avogadro's law of the uniformity of the atomic constitution of gases under like conditions of pressure and temperature.

The latest advocate of the purely circular theory of storms is M. Faye, whose essay appeared in the "Annuaire du Bureau des Longitudes" for 1875; it was written to uphold the old views in opposition to those of Meldrum, as well as to controvert the theory of some continental authors who had lately maintained the efficiency of ascending currents of air, and an upward motion, as the first cause of a whirlwind. He endeavours to establish the reasonableness of most of the theories of the elder cyclonologists, and advances others of a later date—showing that cyclones, and all similar phenomena, are descending currents of air of a conical form, like the whirlpools and eddies that form in water, and that their origin must be sought for in the upper regions of the atmosphere; the progressive motion he takes to be due to the upper part of the cyclone being dragged along by the upper current in which it takes its rise; and he considers that waterspouts and whirlwinds (trombes) come into the same category as cyclones and hurricanes. Faye's proofs being disputed by Peslin and Couste, and the invalidity of his arguments being pointed out,—on returning to a re-discussion of Meldrum's notice of the Mauritius hurricane of February, 1860, he endeavours to show that the storm was really circular, but modified by the action of the S.E. trade-wind—the circular form being well developed in front, while the winds in the rear were centripetal; he at the same time, affirms that observations made at sea are not so accurate as desirable for the purpose, which is a rather good joke, considering that the circular theory was mainly based on data derived from ships' log-books.

A recent American contribution to the theory of storms by Prof. W. Blasius seems to indicate that the storm area is a region of conflict between two opposing currents of air—where the equatorial and polar currents come into collision. Discarding on the one hand the rotary or cyclonic, and on the other the centripetal, theory as proposed respectively by Redfield and Espy, he asserts that storms assume the the form of an ellipse, in which the winds blow in straight lines from the circumference towards the region of the uprising equatorial current, and that the barometrical depression is only a secondary effect of the collision of the two winds, and not the original exciting cause of the storm. He also divides storms into two classes—North-East, or those of winter, and South-East, or those of summer; and shows that each is connected with its own peculiar



cloud. (Fig. 30 is the form of the S.E. storm contrasted with a circular one.) After pointing out that the old rules of the circular theory are worse than useless, he propounds new rules adapted to his two forms of storms. The work is that of an observer, and the statements are given with much positiveness; but the inferences are not always correct, though several of the weak points in meteorological reasoning are well exposed; and the author's remarks are chiefly valuable as showing that the circular theory of storms requires re-consideration.

In passing on to indicate the prevalent hurricane seasons in different regions, and to summarize the old and new rules for storm-sailing, it may be well to quote Mr. BUCHAN on the theory of cyclones:—

"The spiral rotation, instead of the purely circular rotation, of the winds in storms, completely alters the whole complexion of the question of the theory of storms. For since it follows from it that enormous quantities of air are constantly being poured all around into the area of the storm, and since, notwithstanding these accessions tending to increase the pressure, observation shews that the pressure is not thereby increased, but on the contrary sometimes diminished, *we are forced to the conclusion, that, from a large area within and about the centre of the storm a vast ascending current must arise into the upper regions of the atmosphere; and arriving there must flow away over into neighbouring regions.* The physical cause of the ascending currents is to be found in the moist and warm, and therefore light, air which all observation shews to prevail in the front and in the central part of storms. And since most of the rain which accompanies storms falls in those parts of the storm, the barometer will be still further reduced by the removal of the elastic aqueous vapour which is condensed into rain-drops, and by the latent heat set free in the condensation of the vapour."

HURRICANE SEASONS AND STORM-PATHS.

North Atlantic.—M. ANDRE POEY, of Havana, has given a chronological list of every hurricane in the North Atlantic, of which any record can be traced from 1493 to 1855—a period extending over 363 years—and they amount in the aggregate to 355*; their distribution, according to the months in which they occurred, appears to be as follows:—

January	5	May	5	*September*	80
February	7	June	10	*October*	69
March	11	*July*	42	November	17
April	6	*August*	96	December	7

so that the four months, July, August, September and October, may be said to constitute the hurricane season of the North Atlantic, since the record assigns 287 to those months against 68 for the remaining months of the year. The extent of surface may be divided in five areas, as follows:—(1.) The West African; (2.) the West Indian, including the Gulf of Mexico; (3.) the Eastern seaboard of North America; (4.) the Central Atlantic; and (5.) the Northern and Eastern Atlantic; respecting each of which some remarks are necessary.

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* A *few* of the instances recorded are undoubtedly duplicates; others, that occurred within two or three days of each other, are examples of a hurricane following nearly in the track of a predecessor.

(1.) The West African area includes the vicinity of the Cape Verde islands, the Canaries and Madeira. Of the six hurricanes mentioned by Poey, three are stated to have occurred in the month of September off the Cape Verdes,—to which may now be added another, in 1872, also in September, which took a general N.W. by W. direction, from lat. 12° N., long. 22½° W. towards lat. 17° N., long. 30° W. (*Annales Hydrographiques*). Numberless vessels are constantly traversing that part of the Atlantic, yet the records of such storms have hitherto been few, though, in that locality, and during that month, all the elements which give birth to a hurricane are present—the area of lowest pressure lies just south of the islands, near lat. 12° N., long. 20° to 25° W., with two opposing winds (the N.E. Trade and S.W. Monsoon) in close proximity to each other—the Trade increasing in force and pushing to the southward. Of the remaining three hurricanes, one occurred in October, one in November, and the other in May, near the Canaries and Madeira; and of these scanty particulars are known, except that the October storm of 1842 was (according to Sir W. Reid) very destructive, and took a route towards Seville and Lisbon, and that all three approximated to the curvature of the African coast. The Canaries and Madeira are near the southern edge of the region of sub-tropical rains, and gales are expected from the middle of October to December, with the moist S.W. winds.

(2.) The West Indian area, including the Gulf of Mexico and southern part of the Caribbean Sea, is the region of the tropical hurricane in the North Atlantic. The examination of the records of a hundred years gives 215 hurricanes (including *Northers*), which, as regards the month, appear to be distributed as follows:—

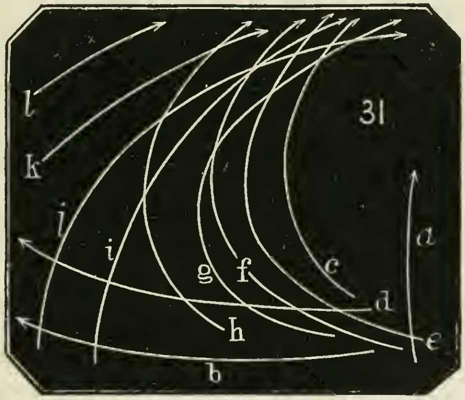
January	5	May	0	*September*	51
February	2	June	4	*October*	40
March	6	*July*	29	November	12
April	1	*August*	59	December	6

so that July, August, September and October constitute the true hurricane season of the West Indies, while that of the *Northers* in the Gulf of Mexico extends from September to March. The southern part of the Caribbean Sea is not wholly exempted, though it cannot be said that there is a hurricane season, since at wide intervals *four* of these storms have taken place in September, *one* in December, and *one* in January; Trinidad more frequently experiences the storm-wave than the storm itself, but of the three hurricanes recorded as having visited the island, one occurred in August and two in September, within an interval of four years.

(3.) The Eastern seaboard of North America is very frequently visited by the West Indian hurricane after recurvature, hence many of those storms already mentioned on p. 90 are common to the two areas. There are others, however, the records of which exclusively relate to the seaboard of the United States, Nova Scotia, and Newfoundland, together with the Bermudas, and their distribution appears to be as follows:—

January	5	May	3	September	5
February	1	June	2	October	10
March	0	July	6	November	7
April	3	August	7	December	7

As areas 1 and 2 are approximately connected, the *paths* of the hurricanes prevalent in the two regions may be taken together; but any attempt to classify them so as to obtain a characteristic or "habitual path" month by month will utterly fail;—yet, from a *seasonal* point, and taking them in the aggregate, the paths of the earlier hurricanes undoubtedly differ in form, and must be determined by a very different system of atmospheric circulation, from those that occur at a later date. Thus Fig. 31 represents that portion of the Atlantic basin included from lat. 10° to 50° N., and from long. 40° to 100° W., with the varied forms of the principal storm-tracks from June to December, both months inclusive. The *typical* progressive movement is first N.W.-ly, and then N.E.-ly.—the place of recurvature being somewhere between lat. 27° and 34°—giving an approximately parabolic curve; but this is not persistent and invariable. At the beginning of the season a storm may take the form (with a short course) represented by curve *a*; occasionally, between June and October (both inclusive), it may assume a more rectilinear direction, towards the West or W.N.W., across the Caribbean Sea, or Gulf of Mexico, as at *b* and *d*; the typical and most predominant form of the West Indian hurricane, with its course along the seaboard of the United States, appears in August and September,—occasionally, however, in October, as shown in curves *c*, *e*, *f* and *g*; but a very common track for the October storm is represented by curves *h*, *i* and *j*—especially the latter, the course being N.N.E. and N.E.; while the November and



December, as well as *some* of the October, storms originate on the American continent, and take an E.N.E. to N.E. course (as *k* and *l*.).

The direction (so far as known) of all the West Indian storm-paths recorded in POEY'S catalogue, was *from the equator towards the poles*, with the exception of one,—that of October 10th, 1847, which, commencing in the Atlantic, eastward of the Windward Islands, crossed Tobago to the mainland of South America—thus, in its westwardly progression, moving *obliquely towards the equator.*

REDFIELD had shown that some of the West Indian hurricanes commenced in the eastern part of the North Atlantic, near the African coast, and it is interesting to find that the Meteorological Office may throw more light on this point. In the latest publication* of that department, Capt. TOYNBEE observes that "the logs of two ships show that a hurricane originated in about 11° N. and 32° W., in August, 1871; at midnight of the 17th its centre seems to have been in about 13½° N. and 38° W.; a hurricane going to the W.N.W. also passed over the island of St. Thomas, at the rate of 17 miles an hour, on the 21st; there can be little doubt this was the same hurricane, and if so, it must have travelled about W. by N. at a rate of nearly 18 miles an hour between midnight of the 17th and its passage over St. Thomas on the 21st;" and, again—"in the part of the sea where some of the West India hurricanes originate, fresh N.E.-ly and S.W.-ly winds are in close contact, and the route which they take is to the southward of a permanent area of high pressure." "A southerly wind is retreating before the advancing N.E. trade during the months in which West India hurricanes prevail," and "this origin between opposing winds agrees with the researches of MELDRUM in Mauritius, and WILLSON in the Bay of Bengal."

(4.) Of the storms of the Central Atlantic very little is known; it was the opinion of Mr. Hunt (Consul) that the heavy gales off the Azores were in some instances, and in some way, related to the West Indian hurricane,—which is not unlikely.

(5.) The meteorology of the Northern and Eastern Atlantic is now receiving considerable attention in the Meteorological Offices of England and France, from the Deutsche Seewarte, and in America. The precise connection of the later autumnal, the winter, and the early spring gales with neighbouring areas of high and low pressure, is a subject yet to be worked out. It is an opinion that a cyclone, properly so called (by which is meant a circular storm) cannot be experienced out of the tropics; but storms of a very cyclonic type are certainly prevalent in high latitudes—north and south—of which numerous instances are on record; there is not sufficient evidence to determine whether these are related to tropical progressive hurricanes, though it is not impossible that the latter might work (widely) round the areas of permanent high pressure; nor is it by any means clear that cyclones or hurricanes first sweep the southern part of the North Atlantic, recurve, and finally reach Europe; it is indeed difficult to trace a storm across from America to Europe. An extensive storm-path may in reality only indicate a succession of storms—produced rapidly, as the result of successive atmospheric disturbances, and newly created local areas of low pressure.

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* Physical Geography of the part of the Atlantic between 20° N. and 10° S., and between 10° to 40° W., by Capt. Toynbee, F.R.A.S., F.R.G.S., &c.

Southern Indian Ocean — Mauritius and Reunion. — Mr. Meldrum and M. Bridet are the great authorities on this part of the ocean, and the former has given very elaborate tables illustrative of the *periodicity of Cyclones and Rainfall in connection with Sun-spot periodicity.* From 1731 to 1844 only 22 Mauritius hurricanes are on record, but this imperfect list might give merely those that were remarkable for their destructive effects on the island. The number of cyclones for each year, from 1847 to 1873, is as follows,—force from 9 to 12 :—

Years.	Hurricanes.	Storms.	Whole Gales.	Strong Gales.	Total Cyclones.
1847	5	0	0	0	5
8	6	2	0	0	8
9	3	2	3	2	10
1850	4	3	1	0	8
1	4	2	1	0	7
2	5	0	3	0	8
3	1	1	5	1	8
4	3	1	0	0	4
5	3	2	0	0	5
6	1	0	2	1	4
7	2	1	1	0	4
8	3	1	3	2	9
9	3	2	6	4	15
1860	7	4	2	0	13
1	5	2	2	2	11
2	4	2	2	2	10
3	5	2	1	1	9
4	2	2	1	0	5
5	2	2	3	0	7
6	1	4	2	1	8
7	0	4	2	0	6
8	3	2	2	0	7
9	3	1	3	2	9
1870	2	1	5	3	11
1	3	2	3	3	11
2	6	5	1	1	13
3	4	5	3	0	12
TOTAL.	90	55	57	25	227

And the following table gives their distribution according to the months of the year :—

June	2	October	2	*February*	45
July	2	*November*	24	*March*	38
August	0	*December*	20	*April*	34
September	0	*January*	46	*May*	22

Thus, January, February, March, and April are essentially the hurricane season, but cyclones are by no means unfrequent in November, December and May. It also seems highly probable that (as a rule) the more easterly, and the lower the latitude of, their origin the lower the parallel on which they will recurve,—the more westerly their place of commencement the greater their sweep in latitude,—and that though they may bend or curve to the southward, they do not always take a S.E.-ly progression, but should they do so their path in that direction is very limited compared with the N.E. track of the West Indian hurricanes.

The cyclones of the Indian Ocean are invariably attended with torrential rains.

The cyclones of the Mozambique Channel in January take a S.W.-ly direction towards the African coast. Those off the N.W. coast of Australia—or, more properly, between it and the south shores of Java, Sumbawa, and Timor—as well as the few off the West coast of Australia, between lat. 23° and 30° S. (*season* from December to May) seem to be more or less influenced by the contour of the Australian land,—but, nevertheless belong to the Southern Indian Ocean type.

Bay of Bengal.—Lieut.-Col. Gastrell and Mr. H. F. Blanford, when discussing the cyclone of October 5th, 1864, which passed over Calcutta, appended some observations on the *probable law of Cyclones in the Bay of Bengal*, of which the following is a general summary :—

Of 52 cyclones, their distribution, according to the months, is,—

January . . .	1	*May*	13	September . .	1
February . .	0	June	3	*October* . . .	14
March . . .	1	July	2	*November* . .	11
April . . .	3	August . . .	2	December . .	1

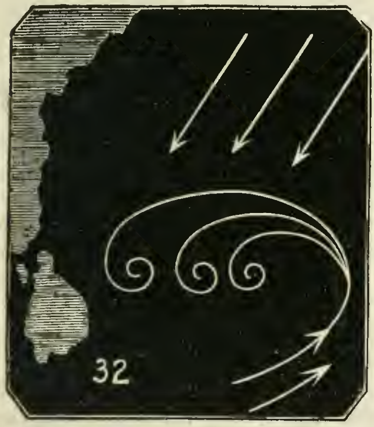
showing that though they are prevalent at the two periods—the change of the monsoons—they are also much more numerous at the end of the S.W. monsoon than at its commencement.

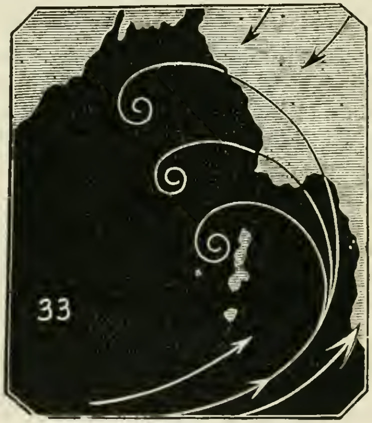
When the storm-paths in the bay are carefully plotted on a chart, it appears that the progression of those that traverse the *north part* of the bay is towards some point between N.W. by W. and N. by W.; while the ordinary path of such as occur in the *south part* of the bay is towards some point between N.W. and West. Disregarding the vicinity of the Andaman Sea (between the islands and the Tenasserim coast), where the tempests are generally entirely local, it appears that the cyclone-paths diverge from three principal foci. The first, which may be called the Northern focus, is a little to the East of the middle of that part of the bay northward of Cape Negrais and the Godavery River; the second, or Andaman focus, is in the immediate vicinity of those islands, ordinarily a little to the West or N.W. of the group ; the third, or Southern focus, is at about mid-distance between Ceylon and the Nicobar Islands ; and, discussed in reference to these foci, it would appear that at the beginning of the S.W. monsoon, cyclones originate in the South part of the bay rather than in the North, while at the end of the S.W. monsoon they appear first in the North, then at the Andamans, and lastly in the South. A similar result is obtained if the bay be considered as divided into only two parts by a line traced from Cape Negrais to the mouth of the Godavery, for example—

Cyclones in the	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
N. half	...	...	...	...	6	3	2	2	1	9	2	...	25
S. half	1	...	1	3	6	...	...	...	...	6	8	1	26

And all the works consulted give but one case of a cyclone that had originated in the North part of the bay between November and May, and no instance of one occuring in the Southern half in February, or during the months when the S.W. monsoon is at its full strength between May and October.

Probable causes which determine the storm-paths:—The cyclones of the extreme South part of the bay tend towards Westward rather than Northward, because at the period when they principally occur the N.E. monsoon is at its height (December, January, *see* Fig. 32):—those originating in the North part of the bay progress towards the N.W. and N. by W., because at the period when they occur the S.W. wind is dominant, and it is but slightly affected by the current from Northward (*see* Fig. 33). The length of the arrows shows the comparative strength of winds.





Put into a practical and concise form, the *periodicity* and *place of origin* of cyclones in the Bay of Bengal may be stated thus:—

I. Cyclones most frequently occur at the period of the change of the monsoons;

II. They are more frequent at the end of the S.W. monsoon (in October and November) than at its commencement (in May and June);

III. They sometimes, though rarely, occur in the north part of the bay and in Bengal during the S.W. monsoon (in July, August, and September); never in the south part;

IV. They sometimes, though rarely, occur at the south extremity of the bay, and between Ceylon and lat. 5° N. during the N.E. monsoon (in December, January, and March); never in the north part;

V. At the change from the N.E. into the S.W. monsoon they occur more frequently in April in the south part of the bay; in May equally over all parts; and in June chiefly (or only?) in the north part of the bay;

VI. At the change from the S.W. into the N.E. monsoon, cyclones are most frequent in October in the north part of the bay; in November they are rare in the north, and frequent in the south, part of the bay.

Again, as to the path of cyclones:—

VII. Those which originate in the north part of the bay usually progress towards N. by W. and N.W. by W.;

VIII. Those which originate *near* the Andaman Islands (not in the Andaman Sea) progress towards N.N.W. and West;

IX. Those that occur in the south part of the bay have usually a progressive motion towards the West, or a little *north* of West.

It is also worthy of note, as probable, that,—

I. Cyclones in the bay are preceded by a very moist and stormy wind from S.W., W.S.W., or West, to the S.W.-ward of the place where they take their rise.

II. Over that part of the bay where they originate, and before their formation, the barometer stands lower than ordinarily, and lower than on the coasts around the bay.

III. This depression is generated at the time when a small general fall of the barometer occurs over the bay and gulf, such as frequently, and at all seasons of the year, interrupts its normal state,—or, in other words, during the passage of an ordinary barometric wave.

IV. A general incurvature of the Southerly current around the place of low barometer precedes the formation of the centre of a cyclone.

V. At the place where the centre is forming the barometer falls still more than around the centre, and continues to fall while the cyclone acquires strength.

VI. The incurving S.W. current being the principal feeder of the cyclone, and the centre being formed more or less towards its Western border, the weather to the East and N.E. of the cyclone is more tempestuous than to the West and N.W. of it.

VII. Within and around the cyclonic centre there is a strong indraught of the ærial currents, so that their direction is a spiral, not a circle, but more approximating to a circle at less than 10 to 15 miles from the centre than at a greater distance.

VIII. In all cases (perhaps only in some cases) cyclones follow no regular path, but a centre may break up or disappear while another is forming at some distance in advance.

The duration of the calm at the centre of the cyclone cannot, however (even when the diameter is known), be taken as the measure of the velocity of the progressive motion of the storm.

The following observations principally apply to Calcutta and Lower Bengal:—

I. If, during the ordinary (tropical) periods of rise the barometer is stationary or low, or if it falls more than two-tenths of an inch during the usual period of fall, bad weather is approaching. The probability is greater with a small gradual decrease of the daily mean through several days.

II. If the wind blowing from S.E. turns to N.E. with a falling barometer, bad weather is probable. The barometer and indications of the weather must then be carefully watched.

III. These signs should especially be noted at the coast stations, and warning given. The sea affords another very useful indication—when a strong swell comes in with gentle East or N.E. breezes.

The following indications are also very important:—

IV. At Ceylon, a stormy moist wind from S.W. or W.S.W., with clouds passing rapidly in the same direction, and the barometer falling, indicate a current which will probably produce bad weather in the bay.

V. When at Ceylon there are indications of a cyclone in the vicinity, there is little chance of its reaching the north part of the bay, but it will probably be felt along the coast of Madras.

VI. If at the Andaman Islands, or Alguada reef, or elsewhere on the Arracan coast, after some days of gentle or variable winds, with a falling barometer, a moist and stormy wind from S.W. arises, the great probability is that there will be bad weather in the north part of the bay.

VII. If after a steady and considerable fall of the barometer, conditions IV. and VI. being fulfilled, a North wind springs up at stations along the west side of the lower part of the bay, a cyclonic centre has probably formed; and if condition I. is fulfilled, it is approaching and at no great distance.

These indications ought to be especially noted at the periods of the change of monsoon.

Mr. Willson, in his Report on the Balasore cyclone (1872), gives the following indications of the probable formation of a cyclone, in the north part of the Bay of Bengal, during the months of May and June, viz.:—

I. The barometer falls steadily for some days round the north of the bay. The fall occurs first to the south-east, at Chittagong and Akyab, and afterwards at Saugor Island, Cuttack, and Calcutta. The barometer at Saugor Island ranges lower than the barometer at Calcutta (normally, at this season it ranges higher).

II. At Calcutta, the winds become light and variable, from S.E. round to N.E. As the disturbance increases, masses of clouds drift from

E.N.E. or N.E., and as the storm approaches, showers are frequent and the wind blows in gusts.

III. At Saugor Island the winds are at first light and variable, working round from S.E. to N.E. As the disturbance increases and the storm approaches the barometer continues to fall steadily; the wind increases in force, with squalls from the N.E., and masses of clouds float rapidly from the same direction. Outside there is a heavy southerly swell.

IV. At Cuttack, or False Point, the winds are at first light and variable from N.N.E., working gradually round, through North to West and W.S.W. As the storm approaches, the wind increases in force, with squalls from West and N.N.W.

V. At Chittagong, the winds are light and very variable, mostly from S.E. and N.E.

VI. At Akyab the winds are at first light, and saturated with moisture, mostly from South and S.E. As the disturbance increases, the wind increases in force, and works gradually round from S.E. to South and S.S.W.

VII. In the bay, along and south of a line drawn from about False Point to Cheduba Island, south-westerly gales, accompanied with torrents of rain, prevail. Standing northwards, the barometer falls, and rises when standing southwards.

Mr. Willson, discussing the Midnapore and Burdwan cyclone of October, 1874, says that there are important distinctions between the storms which visit the shores of Bengal in October and November and those that occur in April and May. The latter are usually generated in the northern part of the Bay of Bengal, when S.W. winds prevail, and those from N.E. are very unusual; the barometer at the same time giving ample warning by falling steadily for several days previously. But the cyclones of October and November, usually originate in the eastern part of the bay, a little north of the Andamans, preceded by many days of bad weather, with a low barometer, in that locality; but the existence of the coming storm is scarcely indicated along the Bengal coast until the outer limit of the gale which surrounds the advancing cyclone is close at hand, and then a decided fall of the barometer takes place: at this season N.E.-ly winds are predominant in the N.W. part of the bay.

The cyclones of October, generated somewhere between lat. 14° N. and 18° N., are those that most frequently visit Bengal, but the storms of November, that originate further south, are often only felt along the Madras coast. The cyclones of this season are also more violent than those of April and May.

It is also worthy of note that he expresses himself as follows, in respect to the origin of these storms:—"Given the existence beforehand of two nearly opposite colliding wind-currents, and hence by necessity an ascending current in the belt between them, the production of a cyclone can be accounted for on dynamical principles."

Arabian Sea and Bombay.—Observations on the cyclones of the

Arabian Sea are not very numerous, but there is sufficient evidence to show their connection with the change of monsoon, as in the Bay of Bengal. Records give,—

January	0	May	1	September	1
February	0	June	2	October	1
March	1	July	0	November	5
April	2	August	0	December	2

They originate in the vicinity of the Maldives or Laccadives, and the earlier ones take a N.W. to N.N.W. course along the land; those at the end of the year trend more to the W.N.W. and West. According to Piddington, one in Oct.-Nov., 1845, came from the Bay of Bengal, and traversed India from Pondicherry to the Malabar coast, pursuing a general westerly course.

China Sea, and West Part of North Pacific.—These two regions may be classed together, because the monsoons are prevalent over both, but the seasonal effect on the typhoons of the area, though sufficiently distinct, is not as well marked as in the case of the cyclones in the Bay of Bengal:—

January	0	May	4	September	22
February	1	June	2	October	15
March	0	July	13	November	12
April	0	August	6	December	1

As regards the China Sea and China coast, there appears, however, to be no particular seasonal storm-path; it may be rectilinear, or curved towards the North, South, or West, at any time, and without any apparent cause; but the preponderating paths are rectilinear and often along the coast. The effect of the high land of Formosa in diverting the storm northward or southward has long been noticed in those that commence eastward of that island; *none cross it* as is often the case with the typhoons off the Philippines. Recurvature is only clearly marked in the Western Pacific and off the Japan coast, especially in the instances of such storms as originate near the Mariana Islands in October; these recurve off the Bonin or Lu-chu Islands. Recurvature has been seen in the hurricanes commencing between the Carolines and Marianas. Typhoons have been experienced off the coast of Japan in July, August, September, and October.

West Coast of Mexico and Lower California.—Storms of a cyclonic character are very frequent in this locality, and thence towards the Sandwich Islands, moving in a N.W. to W.N.W. direction, in July, August, September, and October.

West Coast of North America.—Hurricanes have been recorded moving in a N.E.-ly direction off San Francisco in December and January.

South Pacific.—The tropical regions of the South Pacific are by no means free from hurricanes, and the missionaries have from time to time given accounts of the low islands of some of the Archipelagos being either nearly or completely submerged. At the Fijis they occur in January and February, the path being first S.W., then recurving and following a short S.E.-ly course. At the Friendly Islands they do not seem to recurve, and the season is February and March. The seas between Australia and New Zealand feel the influence of such storms in February and March, the course being towards S.S.W. or S.S.E. to S.E. At New Caledonia cyclones are expected in January and February, and their path may be from N.W. to S.E., or from N.E. to S.W.

Mr. S. J. Whitmee, a missionary of long experience among the islands of the South Pacific, says:—"there is rarely a year without at least one cyclone passing through, or in the neighbourhood of one of the following groups of islands, viz., Fiji, Samoa, or Hervey.

"The cyclone season extends over a greater part of the period during which the *sun* is *south of the equator;* consequently, when the Trade winds from the north reach farthest south. Cyclones are most prevalent about the middle of the season, or rather later than the middle. They rarely visit us earlier than December or January.

"They are usually preceded for a few days by strong northerly winds. During such winds we watch the barometer very carefully, as a sudden fall is a sure indication of a cyclone near at hand."

Extra-tropical Regions.—The storms of high northern and southern latitudes are not unlike those of the tropics, except that they originate in the collision of a different class of winds ; they are essentially cyclonic in character, but their form more nearly approaches that of an ellipse than does the typical hurricane. In a succession of such storms, judiciously used, ships have run down their easting when bound to Australia. They are also common off Cape Horn and the Cape of Good Hope. Storms in extra-tropical regions may occur at any period, but they are most prevalent shortly before, during, and shortly after, the winter of the hemisphere. Among the publications of the Meteorological Office, No. 13 official, and Nos. 2 and 5 non-official, treat on the Atlantic storms between the United States and Europe.

In broad terms the hurricane season, in tropical regions, may be said to begin *near* the time of the summer solstice of each hemisphere;—but, for the West Indies, hurricanes do not, as a rule, occur until *after* the sun has reached its greatest northern declination,—in the Southern Indian Ocean, on the contrary, they may take place a month or more *before* the sun has attained its greatest southern declination,—and then with greater or less frequency throughout the season. The absolute verticality of the sun at the place of origin is not borne out by observation;—had it any effect there would be a marked progression in the direction towards the equator of the places where such storms might be expected to begin,—nearer the tropic early in the season, nearer the equator as the season advanced,—but nothing of this kind is perceptible. These remarks apply more especially to the region of the typical hurricane,—not to that of monsoons, where, owing to the entangled relations of land and water, there may be two distinct hurricane seasons.

There is no instance on record of a hurricane having been encountered *on*, nor of one having *crossed*, the equator, although the simultaneous occurence of two on *opposite sides* of the equator, but 10° to 12° apart, nearly under the same meridian, is well known. The phenomenon of two similar storms raging at the same time on different sides of the equator, is probably incidental to the contiguity of the Monsoon and Trade-wind regions: as cyclones may be expected in the Bay of Bengal as well as in the Southern Indian Ocean during April and May, and again during November and December,—similar meteorological conditions occuring about the same time, within the two regions, may eventuate in the simultaneous production of the same result—a cyclone in each region—but neither in any way connected.

As it is necessary not to confound the strong monsoon winds with a true cyclone, so the same caution is necessary with regard to the winter storms of regions bordering on, or just within, the tropics. Mr. MELDRUM has well described those reaching from the Cape of Good Hope to the Mauritius, and thence to the equator in June, July and August, blowing hard from the southward, accompanied by a high barometer (30·2 to 30·4 inches), and rasing a high sea.

Rate of Progressive Motion of Hurricanes.—The velocity of the progressive motion of the entire area of a hurricane varies not only in different localities, but in the same locality and at the same season. The West Indian storms have been estimated to travel at the rate of 15 to 18 miles an hour (360 to 430 miles a day) previous to reaching the point of recurvature, and to have afterwards passed into the northern part of the North Atlantic at the accelerated speed of 25 to 40 miles per hour,—though it is often much less. In the Bay of Bengal and China Sea the progression, except on rare occasions, does not exceed 9 to 12 miles, and is frequently not over 5 or 6 miles, per hour. There would seem to be greater variation in the Southern Indian Ocean rates, which, while averaging 5 to 10 miles, occasionally reach 14 to 18 miles, an hour, but not unfrequently in the course of their progress appear to be either stationary, or perhaps not travelling at a greater speed than 1 to 2 miles an hour,—which may well be the case if a hurricane with long path is the result of successive cyclonic centres—one bred from the other. THOM was of opinion that the progressive velocity is reduced to 100 miles in 24 hours in about lat. 20° to 22° S., and that beyond 26° S. it scarcely exceeds 50 miles—the causes of support and progression having ceased to exist, a gradual breaking up is begun.

This progressive velocity is independant of the enormous force of the wind blowing around and towards the calm centre, the steady rate of which within the tropics, is rarely less than from 80 to 100 miles per hour, and must often, especially in the fitful gusts, and from the destruction wrought, attain the velocity of 120 to 150 miles per hour.

The Diameter of the Hurricane varies, but it is undoubtedly small at its origin, increasing in dimensions in its onward progression. The West Indian hurricane has been estimated at 500 to 1000 miles across, and expanding to larger dimensions beyond the tropics after recurvature. The Southern Indian Ocean cyclones average from 400 to 600 miles in diameter; while those of the Arabian Sea and Bay of Bengal do not exceed 250 to 350 miles, and the typhoons of China about 50 to 100 miles. In a storm of small dimensions the wind has not of necessity a greater velocity than in one of larger size.

Some time before areas of high and low pressure, and their connection with weather, had come to be a subject of investigation, MAURY and the late Admiral FITZROY had expressed the opinion that no storm could be traced in continuity from the vicinity of the equator, along the shores of the United States, and thence to Europe; and this seems highly probable; circular hurricanes, with one and the same current whirling around a central calm, certainly have nothing in them to perpetuate the prosessive motion; but as the spirally-formed storm is originated through two different currents of air moving in opposite directions towards a low pressure area, and as similar areas already exist along a lengthened line near the equator, and may also be produced by the indirect agency of the storm itself when once commenced and drawing towards it air from all directions, so the storm-path of an apparently continuous tropical hurricane may be made up of a series of storms, the last of which, through changed meteorological conditions and by expansion, finally breaks up in the higher latitudes.

Periodicity of Cyclones and Storms.—Mr. MELDRUM was the first to point out that cyclones in the Indian Ocean are most frequent in years when sun-spots are most numerous; and the late Mr. ANDRE POEY seems to have ascertained a similar connection in the case of the West Indian hurricanes: so also in respect to the rainfall, at least within the tropics,—it appears to be not improbable that it attains a maximum in the years of greatest solar disturbance; and even terrestrial temperature may be similarly affected. Thus, there is "strong matter-of-fact grounds for presuming a connection between the meteorology of our luminary and that of our planet, even although we are in complete ignorance as to the exact nature of the bond." To the navigator this periodicity (if well established) is important to the extent that he will be apprised of the years in which he can scarcely hope to traverse tropical regions without encountering during the season one or more cyclones, or very severe storms.

SUMMARY OF LAWS AND RULES.

OLD RULE FOR FINDING THE CENTRE OF A ROTATORY GALE.—Look to the wind's eye, set its bearing by compass, take the *eighth* point to the *right* thereof, and that will be the centre of the storm if in *North lati-*

tude, but the *eighth* point to the *left* of the direction of the wind will be the bearing of the centre of the storm in *South latitude*. For example:

In North Latitude.		In South Latitude.	
If the Wind be	Centre of Storm will bear from Ship	If the Wind be	Centre of Storm will bear from Ship
North	East	North	West
N.E.	S.E.	N.E.	N.W.
East	South	East	North
S.E.	S.W.	S.E.	N.E.
South	West	South	East
S.W.	N.W.	S.W.	S.E.
West	North	West	South
N.W.	N.E.	N.W.	S.W.

And similarly for the intermediate points.

The approximate distance from the centre might be estimated from the quickness or slowness with which the storm developed itself—from the increasing severity of the squalls, from the faster shifting of the wind, from the rising confusion of a cross swell, and especially from the sudden fluctuations of the barometer.

BUYS BALLOT'S LAW.—The law formulated by BUYS BALLOT on the basis of later and more accurate observations, is simply a more general application of the *Law of Storms* which was first enunciated by REDFIELD and REID, but expressed in terms of the barometer. For instance:—

With your face* to the wind you have—

In the NORTHERN HEMISPHERE,

A high barometer to your left. | A low barometer to your right.

In the SOUTHERN HEMISPHERE,

A low barometer to your left. | A high barometer to your right.

And the force or strength of the wind will depend on the barometric gradients, *i.e.*, it will be approximately proportionate to the amount by which the barometers differ in a given distance.

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* The seaman having been accustomed to "face the wind" in order to determine the direction of the storm's centre, the position is retained in the text, but Buys Ballot's Law is generally spoken of by meteorologists in reference to the *back to the wind*, thus:—

Stand with your back to the wind, and you will have—

In the Northern Hemisphere a low barometer to your left, and
a high barometer to your right.
In the Southern Hemisphere a low barometer to your right, and
a high barometer to your left.

Or otherwise, in the Northern Hemisphere, stand with the left hand towards the place where the barometrical reading is lowest, and with your right hand towards the place where it is highest, and you will have your back to the direction of the wind; and the reverse in the Southern Hemisphere.

But the *lowest* barometer, or centre of depression, is *somewhere* to the right in the Northern Hemisphere, and *somewhere* to the left in the Southern Hemisphere, *not at right angles* to the direction of the wind, as the old law of circular storms implied; for it is an indisputable fact that in cyclones or hurricanes, no less than in all storms, the wind draws spirally inwards (more or less) towards the centre, instead of blowing in circles returning on themselves, and this indraught of the wind across the isobars of the storm's area is especially noticeable along the advancing front. Hence,—

The newer and better RULE FOR FINDING THE CENTRE OF THE STORM will be—

IN THE NORTHERN HEMISPHERE,

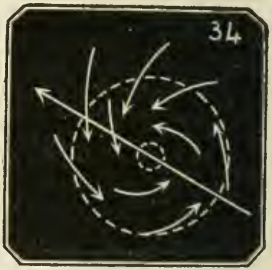
With wind North, the centre will bear more or less *southward* of East.
,, N.E. ,, ,, *southward* of S.E.
,, East ,, ,, *westward* of South.
,, S.E. ,, ,, *westward* of S.W.
,, South ,, ,, *northward* of West.
,, S.W. ,, ,, *northward* of N.W.
,, West ,, ,, *eastward* of North.
,, N.W. ,, ,, *eastward* of N.E.

IN THE SOUTHERN HEMISPHERE,

With wind North, the centre will bear more or less *southward* of West.
,, N.E. ,, ,, *westward* of N.W.
,, East ,, ,, *westward* of North.
,, S.E. ,, ,, *northward* of N.E.
,, South ,, ,, *northward* of East.
,, S.W. ,, ,, *eastward* of S.E.
,, West ,, ,, *eastward* of South.
,, N.W. ,, ,, *southward* of S.W.

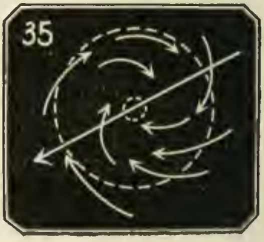
—in both hemispheres according to the angle which the wind makes with the tangent to a circle round the centre of the storm.

In the Northern Hemisphere, the incurvature will, as a rule, be least in the left hand, greatest in the right hand, semicircle—especially in the advancing front (*see* Fig. 34).


34

For the Southern Hemisphere, the incurvature will be least in the right hand, greatest in the left hand, semicircle—and especially in the advancing front (*see* Fig. 35.).

Reverting to the storm-field as divided into a "dangerous" and a "navigable" semicircle (*see* p. 50-51), it would appear that, according to the spiral theory, the wind blows through only 12 points of the compass in the dangerous semicircle,—against 20 in the navigable semicircle,—and these may be grouped as follows:—


35

In the NORTHERN HEMISPHERE:—

Storm moving towards W.N.W.—
In *dangerous* semicircle, winds from North to S.E., round by East;
In *navigable* semicircle, winds from North to S.E., round by West and South.

Storm moving Northward—
In *dangerous* semicircle, winds from East to S.W., round by South;
In *navigable* semicircle, winds from East to S.W., round by North and West.

Storm moving towards E.N.E.—
In *dangerous* semicircle, winds from S.E. to West, round by South;
In *navigable* semicircle, winds from S.E. to West, round by East and North.

In the SOUTHERN HEMISPHERE:—

Storm moving towards W.S.W.—
In *dangerous* semicircle, winds from South to N.E., round by East;
In *navigable* semicircle, winds from South to N.E., round by West and North.

Storm moving Southward—
In *dangerous* semicircle, winds from East to N.W., round by North;
In *navigable* semicircle, winds from East to N.W., round by South and West.

Storm moving towards E.S.E.—
In *dangerous* semicircle, winds from N.E. to West, round by North;
In *navigable* semicircle, winds from N.E. to West, round by East and South.

N.B.—Diagrams 34 and 35 held in positions to show recurvature (northward or southward), and progression to N.E. or S.E., according to the hemisphere, will approximately (but sufficient) indicate the winds in each semicircle.

In both hemispheres, the tendency of the wind in the dangerous semicircle is a matter of serious consideration, for *there* the navigator, being misled by the small amount of change in the wind's direction (everywhere blowing towards the storm-path and centre, and eventually leading thither), unless he has noted its increasing strength, together with the state of the barometer, and general weather appearances, may be gradually nearing, if he is not already at, the centre.

The exceptions to the usual practical rules for manœuvring in cyclones, dependent on the spiral form of the storm, are on the whole few, and only essential (it may be said momentous) in the case where an attempt is made to cross the storm's path—from the dangerous, into the navigable, semicircle: on the circular theory this manœuvre, as well as running before the wind, has never been deemed anything but imprudent, —in the storm where the winds are incurving on the advancing front not only is the centre coming down on the ship, but the ship is heading, if not running, towards that centre.

On the navigable side of the storm, where the winds more nearly approximate to the circular theory, the usual rules may, with ordinary prudence, be accepted as sufficiently safe. *See* p. 54—DOVE'S rules for the respective winds (as given above) of this semicircle, in each hemisphere.

In the dangerous semicircle action is more difficult because there is always the possibility of mistaking a ship's position in the storm,—hence an erroneous manœuvre may be easily adopted.

In the dangerous semicircle the wind, until the ship has approached the centre of the storm, continues to blow more or less constantly from the one direction; but so it does if the ship is on or near the storm's path. In the first case, a sailing vessel would undoubtedly lie-to, or a steamer be put head to wind and sea; in the second, on the contrary, scudding would be adopted; but, in both instances, unless the manœuvre be judiciously executed, and at the right time—or by running where you should lie-to, or the reverse,—it becomes only a question of a few hours, more or less, before the vessel is involved in the centre. The latitude taken in conjunction with the direction of the wind, as indicated on p. 105, for the typical hurricane of the West Indies and Mauritius, may aid in forming a correct opinion as to the course on which the storm is moving, and whether the ship is before its advancing front; but in the China Sea and Northern Indian Ocean, owing to the erratic character of the storm-paths, this guide, if at all trustworthy, fails.

Within the region of tropical hurricanes, at least in the season of of their occurrence, it should never be forgotten that to continue to carry on with a fair wind, which is increasing in strength, while the barometer is falling, is wholly unjustifiable. Whenever doubts arise as to a ship's position in the storm, there always remains the saving manœuvre —of heaving-to,—and then carefully watching the wind and sea, and above all the indications of the barometer.

Unable to get out of a cyclone, and *obliged to lie-to*—since it is advisable to *put the ship on the tack on which she will come up as the wind shifts*—the well-known rule is:—When in the right hand semicircle, heave-to on the *starboard tack*, and when in the left hand semicircle, heave-to on the *port tack*, *in both hemispheres.* A ship heaving-to on the wrong tack in a cyclone must drift into the centre, as it passes onwards. Now, the dangerous semicircle is always to the right of the path in the N. hemisphere, and to the left of the path in the S. hemisphere, therefore starboard tack for the former, and port tack for the latter, must be invariable. There is more scope for manœuvring, and less chance of making mistakes in the navigable semicircle.

When hove-to, if the weather gets worse, the barometer continues to fall, and the wind is steady in direction, but fast increasing in strength, the ship is on the storm-path, and there is but one thing to do, if there be sea-room—to scud; otherwise prepare to meet the calm centre, and the succeeding furious blasts.

Being in the dangerous semicircle, where the winds incurve to the greatest extent, and having made too free with the wind from one direction, increasing in force, then, as the centre is approached, the tendency will be for the winds to veer rapidly, in the N. hemisphere with, in the S. hemisphere against, watch-hands: this will be an unmistakeable sign to heave-to.

When rapidly drawing towards, and close upon, the centre the wind veers very much in accordance with the circular theory.

When in the navigable semicircle it can only be the very perversity of judgment to run into the centre.

For the cyclone season of May, June, and beginning of July in the

Bay of Bengal, Mr. WILLSON, basing his observations on the *in-moving spiral* direction of the wind, remarks that—running up the bay with a S.W. gale, squalls, torrents of rain, a barometer falling rapidly, and every appearance of a cyclone, there is no reason to conclude that the centre bears N.W., and that therefore a North or N.N.E. course is a safe one: the centre, if at a distance, may bear North or N.N.E., and such a course may run the ship into it, particularly if it should be stationary or nearly so: the safest course seems to be to lie-to, and watch the barometer and wind, till the bearing of the centre be known with some certainty. The Balasore cyclone would seem to indicate that the following is a safe rule:—"*Ships coming up the bay in the months of May and June, with fresh South-Westerly gales, accompanied by torrents of rain and falling barometer, should not press northward until the weather improves and the barometer rises steadily.*"

Again,—at the same season—with a cyclone increasing in force, with squalls from N.E., and a heavy southerly swell outside,—"it appears to be unwise for ships, in a good anchorage at Saugor, to put to sea. The great danger is that they may be caught in a cyclone before they have got sea-room to avoid it. Moreover, the pilot vessels will, under the circumstances, be generally off their stations, and ships will be unable to land their pilots. It should be remembered, also, that generally the worst part of a cyclone is the heavy cross sea which accompanies it. In the Balasore cyclone it was this tremendous sea, which is reported never to have been equalled in the bay, which did such damage. This danger would be avoided by not putting to sea until the weather improved."

The remarks of Capt. TOYNBEE on putting to sea on the approach of a cyclone are valuable:—Considering that ships in port are very rarely in a fit state for going to sea (the very fact of their being engaged in discharging or taking in cargo proving that they cannot be in trim), great judgment should be exercised in ordering them to *slip and run.* And in respect to Madras, which, like many other places on the Indian sea-board, does not deserve the name of a port, the conclusion arrived is that when there are signs of a cyclone, each ship should take up a clear berth, in the outer anchorage, in ten or more fathoms, where there is good holding ground in blue mud, with a truer sea than nearer the shore,—veer a good scope of cable before the wind freshens to a gale, and devote all spare time to making snug, and sending down as much top-hamper as possible.

If the ground tackle is good and to be relied on, trusting to ride out the storm may be preferable to putting to sea at once—when the direction of the storm's path being unknown, there exists the danger of being caught on a lee shore. Ships wholly unprepared to encounter bad weather had certainly better remain at anchor; for, by putting to sea under such circumstances, they are only tempting a fate they might otherwise possibly escape.

In reference to the October cyclone (1874) which swept over Midnapore and Burdwan, from S.S.E. to N.N.W. at the progressive rate of 10 miles an hour, Mr. WILLSON observes that—before a cyclone in the bay, and during its approach, strong, squally N.E-ly winds are prevalent *northward* of the storm, and no marked tendency of the wind to veer occurs until the cyclone is close at hand ; at the same time wet, squally gales from S.W-ward are blowing a degree or two to the *south.* An important distinction exists between the storms in the north part of the bay at the beginning of the S.W. monsoon and those that come at its end ; the barometer usually falls steadily and considerably for some days before the occurrence of the former, thus giving ample notice of their approach ; but in October and November the fall of the barometer is usually small—giving little indication of an advancing cyclone until it is close at hand—and there is no warning shift of wind if the vessel is northward of the storm's path, as in April and May, when the shift of wind is from South or S W. to N.E.

[*Caution.*—As a guide to weather changes, in the Bay, the diurnal variation of the barometer is ordinarily 11-hundredths of an inch, and it never exceeds 15-hundredths, except for a storm ; the succession of changes is as follows :—*fall* from 9½h. or 10h. A.M. to 3½h. or 4h. P.M., *rise* from 3½h. or 4h. P.M. to 9½h. or 10h. P.M., *fall* from 9½h. or 10h. P.M. to 3½h. or 4h. A.M., and *rise* from 3½h. or 4h. A.M. to 9½h. or 10h. A.M.; any deviation from this,—as an excessive rise or fall,—or again, fall when it should rise, or rise when it ought to fall, is suspicious, and requires consideration ; and according to the position in the bay, waiting, or proceeding leisurely—feeling the way.]

For the Mauritius cyclones read pp. 75 to 78, but especially 77, as no better authority than Mr. Meldrum could be had.

For the Circular Theory, *see* pp. 46 to 59.

The *Storm Wave* is an undoubted sign that a hurricane is blowing somewhere, but it may be questioned whether it is trustworthy evidence of the direction in which the storm is advancing : in the region of cyclones vessels constantly experience a heavy sea with only ordinary bad weather.

Difference between the "circular" and the "in-moving spiral" form of storms.—The characteristic difference between the two forms of storms, in relation to navigation, lies in this,—and herein consists the danger ;—Winds, which according to the circular theory are held to be safe, unless recklessly used, are, according to the spiral theory, found to exist in the advancing front of the dangerous semicircle, where also their tendency towards the centre is greater than in any other part of the storm-field. As the surrounding body of air, even at a distance, is streaming in the direction of the centre of greatest depression, the ship, by utilizing any of the winds as a fair one, is gradually involved in the cyclone ; then, if she has really been brought to the advancing front of the dangerous semicircle instead of to a part of the storm usually deemed safer,—and the navigator is misled to this extent,—disaster must follow as a consequence. When the Edinburgh Review of 1839, discussing the circular theory, first promulgated the notion of "infallible rules" for storm-sailing, the knell was sounded heralding the loss of innumerable lives and the casting away of an immensity of property.

C. WILSON,

(LATE NORIE & WILSON).

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BRITISH NAVIGATION.

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AND THE

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52.	**The SOUTHERN PART of the NORTH SEA** and Flemish Banks, on a large scale, from the Downs, Harwich, and Orfordness, to Boulogne, Calais, Nieuport, and Ostende, including the Flemish Banks and River Schelde to Antwerp and the Coast of Holland, with the Sea Canal to Rotterdam; with enlarged Plans of the Entrances to Dunkerque Road, Ostende Inner and Outer Roads, Flushing Road, the Maas and Goeree Channels and the Hollandschdiep, from Willemstad to Dortrecht, &c. With a Book of Sailing Directions ...	7	6
53.	**ENGLAND and HOLLAND, on a large scale, from** Beachy Head to the River Humber, on the English Coast, and the opposite Coasts of France and Holland, &c., from Boulogne to the Texel; with an enlarged Plan of the Entrances to the Texel	8	6
	Or with a Book of Sailing Directions................................	10	6

No.		*s.*	*d.*
54.	**The TEXEL to the RIVER HEVER**, on a large scale, including the River Ems, Jahde, Weser, Elbe, and Eider; with Plans of River Elbe entrance, Helgoland, Fedderwarder, Bremerhaven, and the River Eider to Tonning; with a Book of Sailing Directions	7	0
	Nos. 53 and 54 will show the navigation from the English Channel and the Downs to Hamburg, &c., on a large scale.		
55.	**ENGLAND and HOLLAND, from Dungeness to Flamborough Head**, on the English side, and Coast of France, Holland, &c., from Cape Grisnez and Calais to Hamburg, Tonningen and Husum; with Plans of the River Schelde, Entrances to the Texel and the Vlie, and River Humber Or with a Book of Sailing Directions	8 10	0 6
56.	**ELBE and WESER, large scale.—The Entrances to the** Rivers ELBE and WESER, EMS, JAHDE, EIDER, and HEVER to Embden, Leer, Jahde, Bremerlehe, Vegesack, Bremen, Cuxhaven, Gluckstadt, Hamburg, Tonning, Frederichstadt, and Husum; with enlarged Plans of Cuxhaven, Bremerhaven, Fedderwarder, and Helgoland, with Views of Light-houses and Beacons; with a Book of Sailing Directions	5	0
57.	**ELBE, &c., to HJERTING, including TONNING and** ESBJERG, large scale.—The Rivers Jahde, Weser, Elbe and Eider, and Island of Helgoland to Hjerting, with several enlarged Plans of the Principal Harbours, Views of Light-houses, Beacons, &c.; with a Book of Sailing Directions	5	0
58.	**The SKAGER RAK, or SLEEVE, on a large scale**, including the Coasts of Norway and Sweden from Ekersund and the Naze to Christiania, Gottenburg, and part of the Coast of Jutland, with enlarged Plans of Manne Fiord, Christiansand, Arendal, Christiania and Gottenburg; Illustrated with Views of Light-houses and Beacons, &c.	7	6
	This Chart and the following, No. 59 or 62, "Scaw through the Belts," will show the whole navigation from the North Sea to the Baltic on a large and uniform scale.		
59.	**The CATTEGAT, SOUND, and Great and Little Belts**, &c., including the Navigation from Christiania and the Scaw, through the Sound and Grounds, the Great and Little Belts, and the Coast of Holstein and Mecklenberg, to Darser Ort, &c., with enlarged Plans of the Principal Harbours, viz.: — Frederikshaven, Gottenburg, Hallands Fædero, the Sound from the Koll to Falsterbo, &c., including Plan of Elsinore Harbour, also the Sprogoe Channel in the Great Belt, and Kiel Harbour; and Views of the various Light-houses, Beacons, &c. Compiled from the latest Danish and Swedish Surveys; with a Book of Sailing Directions	10	6
	The above Chart is sold in Parts as follows.—		
60.	**PART I.—Extending from Christiania and the Scaw**, to Copenhagen and the Entrances to the Great and Little Belts; with a Book of Sailing Directions	8	0
61.	**PART II.—Extending from the Scaw and Gottenburg**, to Copenhagen and the Entrances to the Great and Little Belts; with a Book of Sailing Directions	5	0
62.	**PART III.—The Scaw through the Belts and the Coast** to Darser Ort, &c.; with a Book of Sailing Directions	8	0

No.		*s.*	*d*
63	The **SOUND**, &c., on a very large scale, from KOLL POINT to FALSTERBO POINT, with Plans of Elsinore Harbour, and the Drogden Channel through the Grounds......	4	0
64	**The BALTIC SEA, including the Cattegat, &c.,** extending to 61° N. lat., including Gefle, in the Gulf of Bothnia, Abo, and Part of the Gulf of Finland, with several Plans, on an enlarged scale, of the Principal Harbours, Views of Light-houses, Beacons, &c. Compiled from the latest Danish, Swedish, Prussian, and Russian Surveys; with a Book of Sailing Directions	8	0
	Mounted on Cloth, coloured, rollers and varnished, for the Counting-house; size 3 ft. 9 in. high, by 4 ft. 8 in. wide ...	25	0
65.	**The GULF of FINLAND, on a large scale, including the** newly-erected Light-houses, &c., and exhibiting the Navigation from the Baltic Sea to St. Petersburg; with Plans of Revel, Port Baltic, Hango Head, the Entrances from Hogland to Frederikshamn and Cronstadt; with a Book of Sailing Directions	7	0
	Mounted on Cloth, coloured, rollers and varnished, for the Counting-house; size 2ft. 5 in. high, by 5 ft. 7 in. wide ...	24	0
66.†	**GULF of BOTHNIA—Southern Part, extends from the** Aland Islands and Channel, to the North Quarken, including Uto, Abo, Nystad, Christinestad, Wasa, and St. Nicholaistad on the Finland Coast, and on the Swedish Coast from Soderarm to Jarnas Hamn and Sorgadden. With enlarged Plans of Gefle Bay, Soderhamn; Entrance to Hudiksvall, Sundsvall, Skags Hamn, Jarnas Hamn, &c., with Views of the principal Light-houses and Beacons; with a Book of Sailing Directions	8	0
	Mounted on Cloth, coloured, rollers and varnished, for the Counting-house; size 3 ft. 6 in. high, by 5 ft. wide	25	0
67.†	**GULF of BOTHNIA—Northern Part, is a continuation** of the above, from Umea and the North Quarken, round the Head of the Gulf to Tornea; Uleoborg; Old and New Carleby, &c.; with enlarged Plans of Ratan Haven and the Entrance to Umea, with Views of Light-houses and Beacons; with a Book of Sailing Directions	6	0
	Mounted on Cloth, coloured, rollers and varnished, for the Counting-house; size 3 ft. 6 in. high, by 3 ft. 9 in. wide ...	21	0
	† *These two Charts show the whole of the Gulf of Bothnia on the largest scale published.*		
68.	**The GULF of BOTHNIA, from the Aland Islands and** Abo, to Sandarne, Hudiksval, Sundsvall, Hernosand, Husum, Holmsund, Umea, Lulea, Tornea, Uleaborg, Brahestead, Wasa, Christinestad, Bjorneborg, and Nystad; with enlarged Plans of the South Quarken, or Alands Haff, the principal entrance to the Gulf; also of the Narrows, or North Quarken, being the intricate and central navigation of the Gulf; and a Plan of Gefle; with a Book of Directions	6	0
	Mounted on Cloth, coloured, rollers and varnished, for the Counting-house; size 3 ft. 5 in. high, by 2 ft. 6 in. wide ...	12	6

No.		s.	d.
69.	**The COAST of NORWAY and the WHITE SEA,** including the Sleeve, North part of Great Britain, Feroe Islands, Jan Mayen Island, the Bear or Cherie Island, with enlarged Plans of the Channels to Drontheim, Christiansund, Hammerfest, &c., and the Mouths of the River Dwina to Archangel ; with a Book of Sailing Directions	10	0
70.	**The WHITE SEA, on a large scale, with enlarged Plans** of the Tokansi Islands, Three Islands Anchorage, Sosnovits or Cross Island, Mouths of the River Dwina to Archangel, the Bay of Onega, and Solovetski Anchorage ; with a Book of Sailing Directions	10	6
71.	**The NORTHERN SEA, comprising the Coast of Greenland,** Iceland, Spitzbergen, Hudson's and Davis's Straits, Baffin's Bay, and Lancaster Sound ; showing the Discoveries of Captains Ross, Parry, Lyon, Scoresby, Austin, McClintock, &c., and adapted principally for the Northern Whale Fishery ; with enlarged Plans of Neil's Harbour, Disco Island, and Bays adjacent, Arksuk Fiord, and Kjartarlik Harbour ; part of Whale Fish Islands, Port Manvers, Fair Haven, Magdalen Bay, Jan Mayen, Cherie or Bear Island, Lancaster Sound, Barren Straits to Melville Isle, Wellington Channel, &c. (*Norie*)	10	6

SOUTHERN NAVIGATION.

GREAT BRITAIN, FRANCE, SPAIN AND PORTUGAL, MEDITERRANEAN SEA, WEST COAST OF AFRICA, AND ATLANTIC ISLANDS.

No.		s.	d.
72.	**The FEROE, SHETLAND, and ORKNEY ISLANDS, to** GIBRALTAR, &c., comprising the navigation from the S.E. Point of ICELAND ; the Coast around GREAT BRITAIN and IRELAND ; the BAY of BISCAY and Coast of PORTUGAL and SPAIN, to GIBRALTAR and part of the MEDITERRANEAN SEA ; also the Coast of Morocco to Mogador, &c. With enlarged Plans of the Pentland Firth, Rockall, Gironde River entrance, Bilbao, Ferrol and Coruna, River Douro to Oporto, River Tagus, Setubal, River Guadalquiver, River Guadiana to Huelva, Cadiz, Ports of Valencia and Barcelona, Mogador Harbour, &c....................................	14	0
	This Fine Chart, engraved in the best and clearest style, is on the largest scale published, showing the complete navigation around Great Britain and Ireland, and is also sold in Parts, as follows :—		
73.	**ORKNEY ISLANDS to the BAY OF BISCAY, including** the FEROE and SHETLAND ISLANDS. Part of the above Chart to Coruna and Finisterre ; with Plans of the Pentland Firth, Rockall, Gironde River Entrance, and Bilbao	10	6
	Mounted on Cloth, coloured, rollers and varnished, for the Counting-house ; size 3 ft. 5 in. high, by 7 ft. wide	35	0

FRANCE, SPAIN AND PORTUGAL COASTS.

The following Charts will be found equal to any published, and constructed and engraved with the greatest care:—

No.		s.	d.
74.	**ENGLAND to the MEDITERRANEAN SEA**, on a large scale, including the navigation from the East Coast of England and Scotland, the Hebrides, or Lewis Islands, and Coast of Ireland, the English Channel, Coasts of France, Spain, and Portugal, &c., to the Mediterranean Sea, and Coast of Marocco to Mogador; with several Enlarged Plans	10	6
	The above is a most useful Chart for vessels bound from Liverpool, Glasgow, or the Coal Ports on the East Coast, to the Mediterranean Sea.		
75.	**FRANCE, SPAIN, and PORTUGAL**, on a large scale, including the English Channel and Bay of Biscay; the Coast of Portugal and Spain to Gibraltar and Barcelona, and Coast of Marocco to Mogador, with several Enlarged Plans of Harbours, and Book of Sailing Directions	7	6
	The above is a most useful Chart for vessels bound from the English or Bristol Channels to the Mediterranean.		
76.	The **BAY of BISCAY**, on a large scale, extending from Ushant to Cape Finisterre, with Enlarged Plans of the River Loire, Bayonne, Port Passage, St. Sebastian, Bilbao, Santona, Santander, Ribadero, Vivero, Barquero, Cedeira, Ferrol, &c., with an additional half-sheet, containing Plans on an enlarged scale, of the Coast from Ushant to the Isle de Sein, including Brest, &c., and the West Coast of France, from the Sables d'Olonne, to the River Gironde; with Book of Sailing Directions..	10	0
77.	The above and Directions, but without the half-sheet of Plans; with Book of Sailing Directions..........................	8	0
78.	The Coast of **PORTUGAL** and **SPAIN**, on a very large scale, from Cape Penas and Santander to Gibraltar; with Plans of the Harbours of Ferrol and Corunna, Vigo, Oporto, the Burlings, Lisbon, Setubal or St. Ubes, Lagos, St. Lucar, Cadiz, Strait and Bay of Gibraltar; with Book of Sailing Directions	7	6
	This Chart with No. 76 *or* 77, *will show the navigation from Ushant to the Mediterranean on a very large scale.*		
79.	A Plan of **AROSA BAY**, from the Spanish Survey of Don J. F. Florez, showing the Navigation to Carril, &c.	1	6

MEDITERRANEAN SEA.

80.	The **MEDITERRANEAN SEA**, with extended true Compass or rhumb lines, including the Adriatic or Gulf of Venice, the Grecian Archipelago and Black Sea, and including part of the Bay of Biscay, to Latitude 47° 30′ N.; with Plans on an enlarged scale of Gibraltar Strait, Malaga, Cartagena, Valencia, Port Palma, Columbretes Rocks, Barcelona, Marseille, Genoa, Leghorn, Bonifacio Strait, Messina Strait, Syracuse, Maltese Islands, Valetta, Corfu North Channel, Syra Harbour, Smyrna Gulf, Alexandria, Port Said, Bombah, Tripoli, Bouja, Algier, Port Scherschel and Tangier; with a Book of Sailing Directions. A useful General Chart	12	0
	Mounted on Cloth, coloured, rollers and varnished, for the Counting-house; size 3 ft. high, by 7 ft. wide..................	32	0

No. *s. d.*

MEDITERRANEAN SEA, IN TWO PARTS.

This New Chart of the Mediterranean Sea, has the advantage of the two Parts being on one scale.

81.† **WESTERN PART of the MEDITERRANEAN SEA,** extends from Cape St. Vincent, Cadiz, and Gibraltar, to Malta, &c., including Corsica, Sardinia, and West Coast of Italy, Sicily, and the Coast of Africa from Cape Spartel to Tunis, &c. With Enlarged Plans of Gibraltar Strait and Bay, Ceuta, Malaga, Almeria Road, Cartagena, Alicante, Valencia, Barcelona, Cette, Marseille, Port Iviza, Port Palma, Port Mahon, Genoa, Leghorn, Piombino Channel, Civita Vecchia, Bay of Naples, Bonifacio and Messina Straits, Valetta, Bay of Oran, and Algier. With a Book of Sailing Directions 12 0

Mounted on Cloth, coloured, rollers and varnished, for the Counting-house; size 3 ft. 6 in. high, by 7 ft. 2 in. wide ... 35 0

82.† **EASTERN PART of the MEDITERRANEAN SEA,** or Levant, extends from Sicily and Malta to Syria and Egypt, including the Archipelago to the Entrance of the Dardanelles, &c. With Enlarged Plans of West End of Sicily, Syracuse, Smyrna, Tripoli, Ben Ghazi, Alexandria, and Port Said, Entrance to Suez Canal. With a Book of Sailing Directions. 12 0

Mounted on Cloth, coloured, rollers and varnished, for the Counting-house; size 3 ft. 6 in. high, by 7 ft. 2 in. wide ... 35 0

† *These two New Charts show the whole navigation from Cape St. Vincent and Gibraltar to Alexandria and Port Said, and the Dardanelles, on a very large scale, and will be found useful for Suez Canal Steamers.*

Special large scale Charts of Port Said, 2s.: Suez Canal, 2s.: Malta and Gozo, 2s. 6d.; Alexandria, 2s. 6d., and of all the Harbours and Ports in the Mediterranean.

MEDITERRANEAN SEA, IN FOUR PARTS.

With extended true Compass or rhumb lines.

83. **PART I.—The Coast of SPAIN and FRANCE from** Cadiz and Gibraltar to Nice; the Coast of Africa, from Salle and Cape Spartel to the Gulf of Storah; with enlarged Plans of Harbours; with a Book of Sailing Directions 8 0

84. **PART II.—The Coast of ITALY from Ventimiglia and** Genoa to the Gulfs of Policastro and St. Euphemia, the Gulf of Taranto, the Adriatic, or Gulf of Venice, the Islands of Corsica, Sardinia, Sicily, Malta, Corfu, Cephalonia, Zante, &c., the COAST OF AFRICA from Bona to Cape Razat; with enlarged Plans of Harbours; with a Book of Sailing Directions 8 0

85. **PART III.—The Coast of Roumelia in GREECE, with** the Northern Part of the Archipelago, the Dardanelles, Sea of Marmora, Bosphorus, the Black Sea, and the Sea of Azov; with enlarged Plans of Harbours; with Book of Sailing Directions 6 0

86. **PART IV.—The Coast of Karamania, Syria, and Egypt,** &c.; with the Southern Part of the Grecian Archipelago, and Islands of Candia and Cyprus; with enlarged Plans of Harbours; with a Book of Sailing Directions 6 0

No.		*s.*	*d.*
87.	The **WEST COAST of ITALY**, &c., on a large scale, extending from MARSEILLE to the STRAIT OF MESSINA, including the Islands of CORSICA, SARDINIA, and the North Coast of Sicily to Marsala, &c.; with enlarged Plans of Marseille, Genoa, Leghorn, Bonifacio Strait, Piombino Channel, Civita Vecchia, Gulf of Naples, Messina and Port of Palermo, illustrated with Views of Coast, &c.; with a Book of Directions .	8	0
88.	The **ADRIATIC** or **GULF of VENICE**, including the COASTS of ALBANIA and GREECE, with the IONIAN ISLANDS, on a large scale; with enlarged Plans of the Harbours of Trieste, Pirano, Venice, Pola and Fasana, Gulf of Kattaro, Port St. Georgia, in the Island of Lissa, Ancona, Port Lossini, Brindisi, Otranto, Taranto, Bay of Durazzo, Argostoli, Zante, Vostizza Navarino, and the North and South Channels of Corfu; with a Book of Sailing Directions........................	10	6
89.	The **GRECIAN ARCHIPELAGO**, and Sea of Marmora, including the Ionian Islands, and the Coast of Karamania, to 31° 40′ E. Long.; with enlarged Plans of Corfu Road, Argostoli Harbour, and Zante Bay, Syra Harbour, Port of Rhodes. Dardanelles Entrance, Bashika Bay, Smyrna Harbour and Khios Strait, Marmarice and Karaghatch Harbours, &c.; with a Book of Sailing Directions..............................	10	6
90.	The **GRECIAN ARCHIPELAGO** (part of No. 89), extending to 19° E. Long., including the IONIAN ISLANDS, with Plans of Corfu Road, Argostoli Harbour, and Zante Bay; with a Book of Sailing Directions	8	0
91.	The **BLACK SEA**, and the Seas of Marmora and Azov; with Plans of the Passage of the Dardanelles, and Bosphorus or Channel of Constantinople, the Entrances of the River Danube, the N.W. Part of the Black Sea from Akkerman and Odessa to Kherson, in all thirty-two enlarged Plans of the Principal Harbours, &c.; with a Book of Sailing Directions	10	6

Captains can be supplied with large scale special Charts of the Marmora Sea, 3s. 6d.; Azov Sea, 2s. 6d.; Dardanelles, 2s. 6d.; Bosphorus, 2s. 6d. &c, &c.

WEST COAST OF AFRICA, FROM GIBRALTAR TO THE CAPE OF GOOD HOPE,

AND

MADEIRA, CANARY, AND CAPE DE VERDE ISLANDS.

92.†	**CHART No. I.—The WESTERN COAST of AFRICA**, &c., on a large scale, from LISBON and GIBRALTAR, to SOUTH CAPE BLANCO, in Latitude 20° 47′ N., including Madeira and the Canary Islands; with Plans, on an enlarged scale, of the River Tagus, Cadiz, and the Ports of Mogador, El-Araish or Larache, Mazighan, and Safi, and the Island of Madeira, &c.	7	0
93.†	**CHART No. II.—The WESTERN COAST of AFRICA** and River Gambia, on a large scale; the continuation of the above Southward to SIERRA LEONE, including the Cape de Verde Islands, with a Plan of Dacar Road in Gorée Bay, the Entrance to the River Gambia, to Bathurst, &c.	4	0

No.		*s.*	*d.*
94.†	**CHART No. III.—The WESTERN COAST of AFRICA,** extending from SIERRA LEONE and the ISLES DE LOS to the CAPE OF GOOD HOPE, with Plans of the Isles de Los, Entrance to River Forecarreah, Mellacoree, and Scarcies, River Sierra Leone, River Sherbro, Cape Palmas, Cape Three Points, Cape Coast Castle, Lagos River, River Benin, Rivers Bonny and Calabar, George and Clarence Bays in Fernando Po, Princes Island, Antonio and West Bays in Princes Island, Corisco Bay, Cape Lopez Bay, St. Thomas Island and St. Anna de Chaves, Anna Bon Island and Anchorage, River Congo, St. Paul de Loando, Benguela Bay, Walwich Bay Ichaboe, Angra Pequena and Possession Islands, Saldanah Bay, Table Bay, &c.	12	0

† *These three Charts will show the navigation of the whole of the West Coast of Africa from Gibraltar to the Cape of Good Hope, on a large and uniform scale.*

95.	**LISBON to GIBRALTAR, MOGADOR, and MADEIRA** ISLAND, on a large scale, with Plans of the River Tagus and Cadiz, and Mogador, the Ports of El-Araish or Larache, Mazighan, and Safi ; (Part of No. 92.)........	4	0
96.	**The CANARY ISLANDS, and MADEIRA, Porto Santo,** &c., on a large scale ; and Part of the Coast of Africa ; with enlarged Plans of Funchal, Santa Cruz, Port Naos, and Arecife; with Views of the Principal Ports, Headlands, &c....	4	0
97.	**The CAPE DE VERDE ISLANDS,** on a large scale, with Plans of Mordeira Bay, English Road, Porto Praya, Tarrafal Bay, and Porto Grande ; with a Book of Directions .	4	0

For a Chart of the Islands of the AZORES, see No. 101 under "Atlantic Navigation," next page.

WESTERN NAVIGATION.

NORTH AND SOUTH ATLANTIC, NEWFOUNDLAND, NOVA SCOTIA, UNITED STATES OF NORTH AMERICA, GULF OF MEXICO, WEST INDIES, BRAZIL, SOUTH AMERICA, PACIFIC OCEAN, AND ISLANDS OF THE AZORES, &c.

98.	**The NORTH ATLANTIC OCEAN** ; on a large scale ; comprehending part of the Coast of Europe, Africa, America, and the West Indies, and extending from Greenland to the 6° of South Latitude ; with Plans of Funchal Bay, the Fayal Channel, Punta Delgada (San Miguel), and the Eastern Narrows Bermuda Islands ; with observations on the Gulf Stream, and General Currents, Trade Winds, &c. ; also tracks for sailing vessels and steamers, and lines of equal magnetic variation This Chart will be found equal to any hitherto published, and compiled from the latest authorities	7	6
	Mounted on Cloth, coloured, rollers and varnished, for the Counting-house ; size, 3 ft. 5 in. high, by 4 ft. 6 in. wide ...	24	0

No.		*s.*	*d.*
99.	**The SOUTH ATLANTIC OCEAN**; on a large scale; extending from the Equator to Cape Horn, &c., to 63° 30′ South Latitude; and including the Islands of St. Helena, Ascension, and the Falklands; and the Coast of Africa to Cape of Good Hope; with enlarged Plans of Pernambuco, Rio de Janeiro, Port William and Stanley Harbour (Falklands), St. Helena Anchorage, and Table and False Bays; illustrated with views, and containing much valuable information on Winds, Currents, Temperature of Water, Tracks, &c. A companion Chart to the North Atlantic	7	6
	Mounted on Cloth, coloured, rollers and varnished, for the Counting-house; size, 3 ft. 5 in. high, by 4 ft. 6 in. wide...	24	0
100.	**ENGLAND to the CAPE of GOOD HOPE, including** the NORTH and SOUTH ATLANTIC, showing the Navigation from England to the Coast of Brazil, River Plate, St. Helena, Cape of Good Hope, &c., with the Routes usually made between those places (*Norie*)	10	6
101.	**The AZORES or WESTERN ISLANDS, on a very large** scale, with Plans, on an enlarged scale of the Island of St. Michael, Punta Delgada and Villa Franca, Angra and Praya Bays, Villa de Port and St. Lourenzo, Horta and Pim Bays, Fayal Channel, Formigas Rocks, and Dollabarat Shoals, and illustrated with views, a beautiful and finely engraved Chart	5	0

NOTE.—*For Cape Verde, Madeira, and Canary Islands, see under heading "West Coast of Africa," preceding page.*

CHARTS OF THE COASTS OF NORTH AMERICA, FROM THE STRAIT OF BELLE ISLE TO THE GULF OF FLORIDA.

No.		*s.*	*d.*
102.	**BELLE ISLE to BOSTON, including the Banks and** Island of Newfoundland, Nova Scotia, Prince Edward Island, Gulf and River St. Lawrence, Bay of Fundy, and Coast of the United States to Boston; with particular Plans of the Harbours of Halifax, St. John's Newfoundland, Island of St. Pierre, Liverpool Bay, Nova Scotia, St. Paul's Island, St. Andrew, St. John New Brunswick, Boston, &c.; with part of the River St. Lawrence, on an enlarged scale. Compiled from the latest Surveys, including those by Captain Bayfield, R.N.; with a Book of Sailing Directions	12	0
	Mounted on Cloth, coloured, rollers and varnished, for the Counting-house; size, 3 ft. 5 in. high, by 5 ft. 8 in. wide...	30	0
103.	**The Island and Banks of NEWFOUNDLAND** (part of the preceding); with a Book of Sailing Directions..............	8	0
104.	**The GULF and RIVER ST. LAWRENCE**, on a large scale, extending from St. George Bay, Newfoundland, to Quebec; with Plans of Quebec Harbour, Miramichi Bay, Gaspé Bay and Harbour; also Plans on an enlarged scale of the River from Bic Island to Quebec, and illustrated with some views; with a Book of Sailing Directions	10	6
	Mounted on Cloth, coloured, rollers and varnished, for the Counting-house; size, 3 ft. 5 in. high, by 4 ft. 9 in. wide...	27	6

No.		s.	d.
105.	**CAPE CANSO to PHILADELPHIA** with enlarged Plans of the Harbours of New York. Newport, Boston, New Bedford, Newburyport, Portsmouth, Portland, Liverpool Bay, St. John New Brunswick, Shelburne, and Halifax Harbour; with Book of Sailing Directions	14	0
106.	**NOVA SCOTIA and the BAY of FUNDY from the Gut** of Canso to Penobscot Bay, including the Bay of Fundy, Chignecto Bay, Basin of Mines, and Sable Islands; with enlarged Plans of the Principal Harbours; with a Book of Sailing Directions (Part of the above)	7	0
107.	**BOSTON to the STRAIT of FLORIDA and HAVANA,** with Plans on an enlarged scale. of New York Harbour, Entrance to the Delaware, Shoals off Cape Charles, Shoals off Cape Hatteras, Ocracoke Inlet, Cape Fear River entrance, (Wilmington), Frying Pan Shoals, Charleston Harbour, Savannah River, St. John River, &c.; with a Book of Sailing Directions	14	0
	The above beautifully engraved Chart is from the surveys made by officers engaged in the survey of the Coast of the United States, and will be found equal to any published.		
	NOTE.—*This and No.* 102, *Belle Isle to Boston, will show the complete navigation of the East Coast of North America.*		
	The above Chart is sold in Parts as follows :—		
108.	**BOSTON to CAPE LOOK OUT, including NEW YORK,** DELAWARE, CHESAPEAKE, &c.; with Plans and a Book of Sailing Directions	8	0
109.	**CAPE FEAR to FLORIDA, with Plans ; with a Book** of Sailing Directions	8	0
	The above two Charts are the same as No. 107, *but in two parts.*		
110.	**BOSTON to CHARLESTON, SAVANNAH, and St.** Augustine. with Plans and Book of Sailing Directions	12	0
111.	**PHILADELPHIA to the GULF of FLORIDA and** HAVANA, &c.; with a Book of Sailing Directions	12	0
	This Chart and No. 105, *Cape Canso to Philadelphia, will show the navigation from C. Canso to Havana on a large scale.*		

THE WEST INDIES, GULF OF MEXICO, &c.

No.		s.	d.
112.	**A General Chart of the WEST INDIES, including the** GULF OF MEXICO; with enlarged Plans of Havana, Jamaica Island, Kingston Harbour, Vera Cruz, Galveston, San Luis, Tampico Harbour, and Sabine River Entrance, Greytown Harbour, Puerto de Naos or Limon Bay, and Chagres; with Views of the Land, Lighthouses, &c.	12	0
	Mounted on Cloth, coloured, rollers and varnished, for the Counting-house; size, 3 ft. 8 in. high, by 5 ft. 8 in. wide...	32	0
113.	**The WEST INDIA DIRECTORY; being a complete** Sailing Directory for the whole of the West Indies and Gulf of Mexico. Bound in Cloth	8	0
114.	**A General Chart of the WEST INDIES and the Coast** of AMERICA, from East Florida to Guayana. including the Gulf of Mexico, Bay of Honduras, and the Caribbean Sea; with Plans of Vera Cruz and Havana	7	6
	Mounted on Cloth, coloured, rollers and varnished, for the Counting-house; size, 2 ft. 10 in. high, by 4 ft. 5 in. wide.	21	0

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